Broadening the Impact of a Low-Cost Heat Pump Fruit Dryer for Developing Countries

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ABSTRACT

The goal of our project was to improve the operations of a low-cost heat pump fruit dryer for developing countries and facilitate its transfer to new locations. To accomplish this goal, we designed an analytical tool consisting of relevant questions to evaluate technology transfer processes. After administering the questions through interviews with stakeholders, we built a modified version of the dryer and created a user manual for its construction and operation to bring greater autonomy to communities during future expansions.

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CHAPTER 1: Introduction

One third of food produced worldwide is never consumed (World Food Programme: Feeding Hunger Worldwide, 2015). This issue is especially prevalent in developing countries, where approximately 70% of fruits and vegetables spoil due to a lack of infrastructure and storage space for production surplus (Bertsch, Garrison, & Lukacs, 2015). To minimize this problem, many farmers rely on food processing techniques to preserve fruit during storage and potentially export. Methods of food processing for fruits and vegetables include canning, freezing, boiling, and drying. By exporting processed fruit to other countries, fruits that would otherwise be discarded are sold, bringing revenue to the communities producing the fruit and eliminating waste. Organizations from developed countries have been working together with local communities in developing countries to address the needs and opportunities associated with the increasing demand for processed fruit. The transfer of technology from developed countries has made machines, such as fruit dryers, available and applicable to developing countries. Each group that is involved with the implementation process has different motivations and capabilities, which leads to a vast and intricate network of stakeholders. Evaluating whether or not the needs of the communities being affected by the technology are aligned with the goals of the organization leading the implementation remains one of the largest challenges in any technology transfer process.

Dried fruits have gained importance over the past years worldwide, leading to increasing opportunities for fruit dryer implementations. In the United States for example, dried fruits became a healthy snack option to substitute the traditional chips and candies (McKitterick, 2015). Dried fruits retain most of the nutrients of fresh fruits, and thus offer many health benefits. Studies confirm that they reduce cholesterol, as well as the risk of heart disease, diabetes and certain types of cancer (International Nut and Dried Fruit, n.d.). To support the growing demand for healthier options globally, the production of dried fruits has increased. The most common fruit dryers used in developing countries are solar and gas dryers, but both have drawbacks. Solar dryers cannot operate during the rainy season, which is a problem because many developing countries are located in tropical and subtropical regions of high temperatures and precipitation levels. Gas dryers are subject to the fluctuating price of gas, emit high levels of CO_2, and do not operate under a constant temperature, causing 30% of the fruits to be discarded due to discoloration and burning (Bertsch et al., 2015). Because of these disadvantages, alternative drying methods are frequently being sought, leading to challenging technology transfer processes in culturally diverse and economically fragile countries (Darrow & Saxenian, 1975; Hazeltine & Bull, 2003; Klassen, 2011).

Extensive research has been conducted to evaluate the effectiveness of implementing different drying methods in developing countries. If technology transfer is attempted without the necessary prior research and understanding, the process can not only fail but also damage the community where the implementation occurs. The low cost fruit dryer was created with the purpose of benefiting communities as a whole, and could potentially worsen issues in communities if it falls into the hands of someone with different motives or is not suited to the needs of the community in the first place. Several organizations have conducted studies to determine the most important considerations to examine before beginning a technology transfer process. Some of these organizations include the Food and Agriculture Organization of the United Nations (FAO) (Anstee et. al, 1996) and the United Nations Industrial Development Organization (UNIDO) (Fellows, P., 2004). They conducted experiments with different methods of fruit drying, further clarifying the advantages and disadvantages of each to the local communities in developing countries. In 2008, the NTB-Interstate University of Applied Sciences and Technology (NTB), located in Switzerland, developed a low-cost heat pump fruit dryer with Akos Lukacs from the ecological center Ökozentrum to help people in developing countries earn money using sustainable technology (Bertsch, S., Gschwend, A., & Lukacs, A., 2012). Heat pump dryers have several advantages, including energy-efficient heat recovery, reduced CO_2 emissions compared to gas dryers, weather independent drying, and the use of lower drying temperatures (i.e., higher quality fruit). These attributes allow the processed fruit to be sold at a higher price, benefiting the fruit dryer operators, farmers, and the local economy of these countries (Bertsch et al., 2012). NTB's and Ökozentrum's dryer was implemented in Burkina Faso in 2010 and in Costa Rica in 2014. Possible locations for further expansion are continuously being explored, along with methods to make each transfer of the fruit dryer more effective and beneficial to the fruit producers.

The implementations of the low cost fruit dryer were effective in their goal of increasing farmers' income through the sale of premium dried fruits (Huber & Obermeyer, 2011); nevertheless, there are still areas for improvement and potential expansion. One of the largest issues currently is that the know-how regarding the fruit dryer assembly, operation, and maintenance has not yet been successfully transferred to local people in the developing countries, making them dependent on NTB and Ökozentrum (S. Bertsch, personal communication, February 9, 2015). The interaction between local communities and foreign technicians represents challenges that can occur during any technology transfer process because it involves aligning goals, adjusting pace, and learning the most effective way to communicate. Reducing the reliance of the local communities on NTB and Ökozentrum is a difficult and ongoing task, and requires improvements to be made to the technology transfer process itself. To examine this process, we had to evaluate the previous implementations in Burkina Faso and Costa Rica to detect any significant drawbacks and understand how the dryers were socially, culturally, and economically received.

The primary goal of our project was to aid NTB and Ökozentrum to broaden the impact of their fruit dryer in developing countries. This included not only improving the fruit drying operation as a whole, but also facilitating its transfer to different locations. To accomplish this goal, we collaborated with NTB to understand the fruit dryer's previous implementations and optimize the technology transfer process for future expansions. We first developed an analytical tool and then applied it to the current implementations of the dryer to understand its limitations and methods of improving them. The analytical tool consisted of questions to consider when transferring new technology into developing countries, and guided our group's interview plans for NTB's major partners in the project. After talking to the partners, we concluded that the best way our project could improve the technology transfer process and aid NTB and Ökozentrum in the future implementations of the dryer would be through the creation of a user manual. We first built - together with NTB technicians - a fruit dryer with some modifications, and then wrote a manual that aims to give autonomy to local communities in developing countries by allowing them to build, install and operate the fruit dryer independently from NTB and Ökozentrum. Lastly, we provided a list of recommendations for future expansions and improvements that can be made to the fruit dryer, the user manual, and the overall technology transfer process.

CHAPTER 2: Background

In developing countries, the economy is driven mainly by agriculture. It is a common practice for farmers to produce agricultural goods in excess and be left with a large surplus. Due to a lack of storage infrastructure and to the high air freight costs to sell products to the external market, approximately 70% of fruits and vegetables spoil in tropical and subtropical developing countries- a high value compared to 5% in Europe (Bertsch et al., 2015). Meanwhile, there is an increasing demand in developed countries for dried tropical fruits. One alternative found by some farmers and cooperatives to solve both problems at once was to dry the excess fruit. Drying offers a protection against dirt, insects, and other contaminants (Barrett, Ringeise, & Stroeve, 2014), thus preserving food that could not be immediately sold. Drying also increases farmers' revenue when exporting dried fruits to the external market. This therefore allows the farmers to reduce waste and have an additional source of income.

For years, many individuals and organizations in developed countries have attempted to implement fruit dryers in developing countries to help local farmers. The process of transferring technology is complicated and involves an intricate network of people with different cultures, capabilities, and motivations. Often times, when people cross borders with the good intention of helping communities, problems arise due to cultural, environmental, mechanical, and economic aspects. Therefore, to prevent failures during implementation, a detailed analysis should be conducted beforehand.

To better understand the process of fruit drying and what is required to implement appropriate technology, this section will analyze NTB University's approach to transfer technology to different locations. This section will also examine cultural and environmental aspects of each location, and will discuss considerations when searching for future implementation sites.

2.1 Fruit Drying Overview

When fruit is dried, it undergoes a process to have water removed from its interior. This serves as a method of food preservation, since bacteria cannot grow and spoil fruit without the presence of moisture. Dried fruit has a high processing temperature, a low pH, low water content, and a presence of natural antimicrobial compounds, making it an exceptionally stable food with no known incidents of foodborne illness (Main, 2014).

Two prominent methods of fruit drying include solar drying and gas drying. Solar dryers use the sun as a heat source and often use reflective foil to significantly increase the temperature inside the dryer. Ventilators expedite the removal of moisture from the fruit, decreasing the drying time. Gas dryers function in a similar manner, but use gas as a fuel source to increase the temperature inside the dryer (Harrison, 1914). The earliest records of sun drying fruit can be found in Mesopotamian tablets dating around 1700 B.C (Main, 2014). Since then, various other fruit drying methods have been developed such as drum drying, refractance window drying and freeze drying. Drum dryers are considered to be energy efficient and use steam to heat a material applied to the interior of a drum, with drying times ranging from a few seconds to dozens of seconds (Tang, Feng, & Shen, 2003). Refractance window drying uses circulating water at atmospheric pressure to carry thermal energy to the fruit and drying it within a few minutes (Abonyi, Tang, & Edwards, 1999). Freeze drying takes considerably longer than the previous two methods, as fruit is typically frozen overnight or for up to 48 hours (Paul, Friedrich, & Enkerud, 2010).

Dried fruit is produced in large quantities in many developing countries, for both local consumption and export. However, much of the dried fruit still contains a large percentage of its initial moisture, which makes it highly susceptible to spoilage if not stored in temperature-controlled facilities. To improve this, modern methods of drying are being implemented in some areas. Modern dryers produce higher quality fruit products, but most can only be afforded by commercial companies. NTB-Interstate University of Applied Sciences and Technology, together with Ökozentrum, has developed a heat pump dryer that uses less energy, emits less CO_2, and operates at lower temperatures than conventional oven dryers (Teeboonma, Tiansuwan, & Soponronnarit, 2003).

2.2 NTB and the Low-cost Heat Pump Fruit Dryer

The NTB-Interstate University of Applied Sciences and Technology (NTB) is located in Buchs (Figure 1), Switzerland, in the St. Gallen canton and was founded in 1970 with the purpose of conducting applied research and developing new technology (NTB, 2015). NTB is a public university with education funded by the Swiss government, and research funded either by companies or government grants. NTB consists of seven institutes, and our project is being conducted under the Institute of Energy Systems (IES) (S. Bertsch, personal communication, February 9, 2015). This branch of the university is led by our liaison, Stefan Bertsch, who works with photovoltaics, refrigeration equipment, power electronics, and heat pumps.

Figure 1. NTB-Interstate University of Applied Sciences and Technology (NTB, 2015)

In 2008, Stefan Bertsch collaborated with Akos Lukacs, a partner who previously worked for the ecological center Ökozentrum, to create a low cost fruit dryer for developing countries. NTB has provided advising and preparation assistance, material for one prototype, as well as shop labor as necessary (S. Bertsch, personal communication, February 9, 2015). Burkina Faso was the first to receive this fruit dryer in 2010, due to the country's heavy reliance on agriculture and connections Ökozentrum had previously established there. Another dryer was implemented in the country in 2013 (C. Huber, personal communication, March 18, 2015). In addition, a fruit dryer was established in Costa Rica in 2014 to expand the country's methods of fruit drying (S. Bertsch, personal communication, January 29, 2015). NTB is working primarily with the ecological center Ökozentrum and Akos Lukacs on this project, as well as Isomet Burkina Faso (a solar power, renewable energy and metal industry company), Racine Kambwole (a refrigeration specialist in Burkina Faso), Université Burkina Faso, Myclimate Schweiz (a climate protection and carbon offset company), Repic (a corporation that promotes renewable energy and energy efficiency internationally), and the fair-trade company Gebana Afrique (S. Bertsch, personal communication, February 9, 2015). Finally, using air-conditioning technology from Frigoris AG Kältetechnik, NTB and Ökozentrum have been working together to design, build, and implement the fruit dryers.

Our sponsor's mission in this project is to create jobs and improve infrastructure in developing countries using environmentally friendly and sustainable technology. This project also serves as a valuable learning experience for students in Switzerland (S. Bertsch, personal communication, February 9, 2015). Environmental and cultural challenges were experienced during the previous implementations, therefore careful consideration from NTB is necessary in selecting future communities to implement the fruit dryer. NTB hopes to improve the communities without overburdening their society with inappropriate technology.

2.2.1 Fruit Dryer Mechanics and Operations

During the rainy season, fruits cannot be dried using the traditional solar method. With the price of gas constantly varying, alternative methods for the gas-fired furnaces were sought. Thinking of countries under subtropical conditions (high heat and humidity), NTB and Ökozentrum developed a fruit dryer system with a low-cost heat pump technology in 2008 (Systems, 2014). The system is based on a process with closed air circulation so that external environmental influences, such as high temperatures and humidity, are eliminated (Bertsch et al., 2012).

When explaining the fruit dryer mechanics, Professor Stefan Bertsch compared the system to a clothes dryer or air conditioner (S. Bertsch, personal communication, January 29, 2015). Figure 2 depicts a schematic of how the fruit dryer works. The heat pump process is cyclic. As fruits dry, moisture is released from the fruit through evaporation and rises toward the ceiling. When this vapor comes in contact with the colder ceiling, it partially condenses and is drawn towards the back compartment of the dryer due to the ventilator. This moisture then passes through the first heat exchanger, called the evaporator. The evaporator is filled with the refrigerant R134-a in a cold, low pressure, liquid state. As the warmer moisture passes through, it loses heat to the refrigerant, leading to the coolant's evaporation. As a consequence, the moist water vapor fully condenses, and deionized water can be collected as a by-product. With the addition of salt, the water can become safe for consumption. The resulting refrigerant vapor is not hot enough to warm the air to dry the fruits, so it passes through a compressor, where its temperature and pressure are increased. Finally, the hot, high pressure refrigerant vapor passes through the second heat exchanger, called the condenser. The refrigerant warms up the ambient air surrounding the condenser, and a radial ventilator with adjustable speed blows this air out, re-starting the cycle. The refrigerant, in turn, condenses, and is sent back to the evaporator to serve as a coolant again.

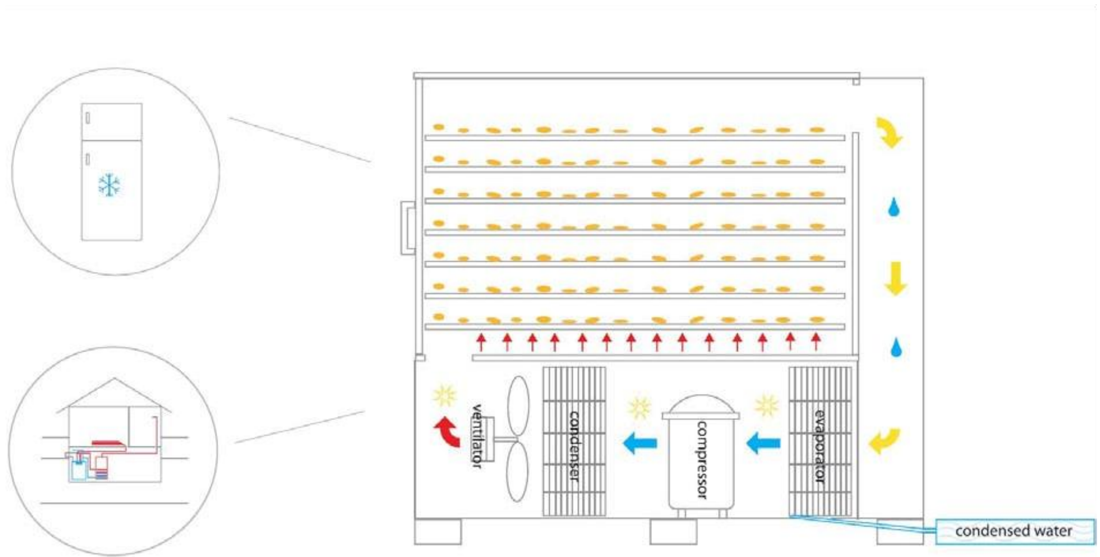

Figure 2. NTB's fruit dryer mechanics (Bertsch et al., 2012)

Physically, as shown on Figure 3, the fruit dryer resembles a household refrigerator, only made of wood. Pieces of freshly cut fruits are placed on mosquito netting that covers the wooden pallets. The nets are necessary to prevent the sticking of fruits to the pallets, thus facilitating the removal of fruits at the end of the process. However, the nets hinder the passage of air through the pallets, so they are still not ideal (S. Bertsch, personal communication, January 29, 2015). The pallets are then placed inside the wooden box, as seen in Figure 4, where the fruit drying procedure begins.

Figure 3. Front view of NTB's fruit dryer (Bertsch et al., 2015)

Figure 4. Wooden pallets with mosquito netting (Bertsch et al., 2015)

The fruit drying operation is straight-forward, as depicted in the production stages in Figure 5. The fresh fruit is first purchased from local farmers and brought to the fruit drying plant. Once the fruit arrives, it is cleaned, peeled, cut, and then dried using the fruit dryer. After drying, the fruit is packaged and shipped to be sold in local and global markets.

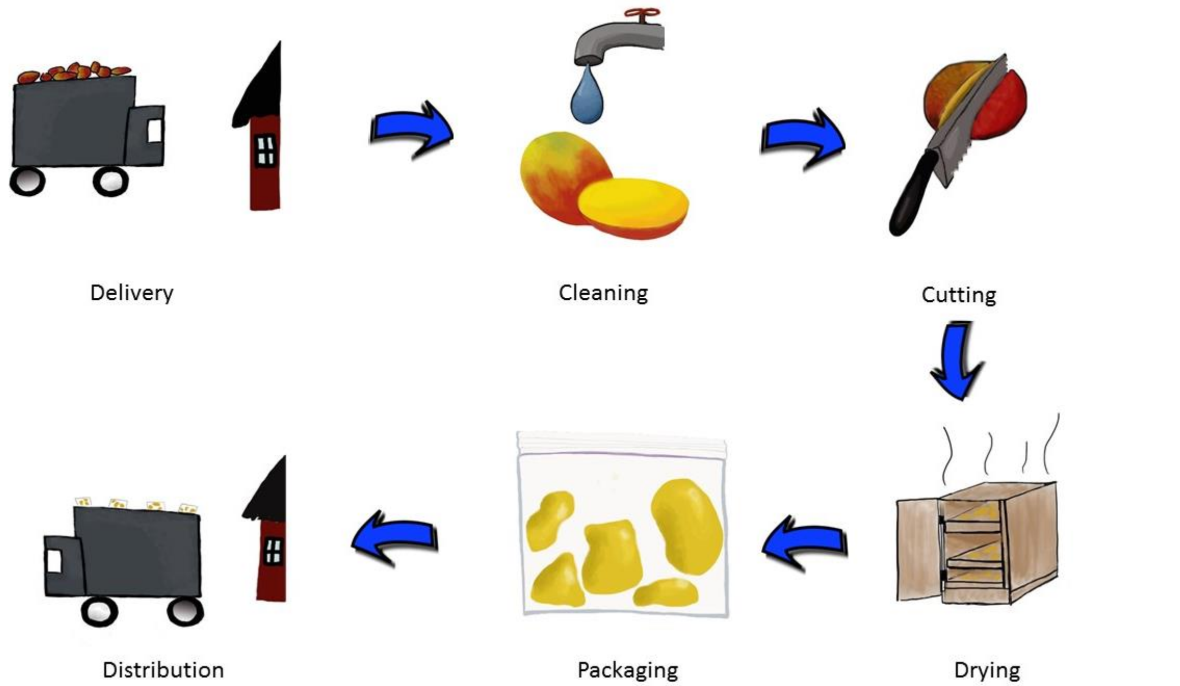

Figure 5. Fruit drying production stages

Compared to traditional fruit drying methods, NTB's and Ökozentrum's fruit dryer offers many advantages. While a solar dryer cannot operate during the rainy seasons, the heat pump technology is weather independent, allowing for a year-round, optimal operation. Compared to a gas dryer, CO_2 emissions are reduced by 65%, energy consumption is lowered, and operating costs are reduced by over 50% (Bertsch et al., 2012; Institute for Energy Systems, 2014). One reason for reduced operating costs is the fact that the energy price for dried mangoes decreases from €0.33/kg to €0.17/kg (Bertsch et al., 2015). Capital costs are also reduced due to low material costs - about 2000 francs are needed for an entire system (Bertsch et al., 2012). In addition, in a heat pump dryer fruits are dried in a much gentler way (at a lower, homogeneous temperature) and are not exposed to hot combustion gases. The result of a gentler procedure is dried fruits with higher quality (vitamins, taste, and appearance) and higher market value. Another advantage is the absence of toxic gases, thus increasing safety in the workspace. Lastly, the by-product of the process is deionized clean water that condenses after passing through the evaporator and can be used for consumption with the addition of salt.

Currently, there are two main issues regarding the heat pump dryer. First, it is dependent on electricity, an unreliable source of energy in Burkina Faso (S. Bertsch, personal communication, January 29, 2015). This problem might be solved with renewable energy sources, as explained in the next section. Additionally, the know-how regarding the fruit dryer assembly, operation, and maintenance has not yet been successfully transferred to local people in the developing countries, making them dependent on NTB and Ökozentrum (Bertsch et al., 2015).

To assess the results of the drying process, the fruit dryer is equipped with various sensors, allowing the system to be monitored through data transfer. The data collected is then analyzed by Ökozentrum and partners located on the implementation site to track the fruit dryer's performance (Bertsch et al., 2015).

2.2.2 Energy source

The energy source for the NTB fruit dryer is a significant obstacle, mostly due to the locations in which it is being operated. Burkina Faso is not a large producer of electricity, and power outages are very common, occurring as much as ten times per day (S. Bertsch, personal communication, January 29, 2015). NTB is in the process of designing their fruit dryer to be independent from the power grid in Burkina Faso so that even if the grid is operating and functional, it is not burdened by numerous heat pump dryers.

To minimize this problem, photovoltaic systems were installed in Burkina Faso as a back-up power source to cover a significant portion of the energy consumption of the fruit dryer (Huber, n.d.). Burkina Faso's location places the country at a favorable orientation to the sun throughout the whole year, providing the country with an average of 8 hours of sunlight per day (Huber & Obermeyer, 2011). However, photovoltaic panels by themselves cannot sustain the power required by the normal operation of fruit dryer (Huber, n.d.).

Another possible power source is biogas emitted by rotting fruit (Bertsch et al., 2012). During the harvest season in Burkina Faso, only 20-30% of the harvested fruit is able to be dried and sold, while the rest become spoiled (S. Bertsch, personal communication, January 29, 2015). This leads to a major opportunity for energy production, but the system is unlikely to be reliable enough for year-round power production on its own. By combining these two energy production methods, the fruit dryers might be reliably powered independently from Burkina Faso's energy grid (Bertsch et al., 2012).

2.2.3 Funding

When Akos Lukacs first envisioned the project, he obtained funds mainly from REPIC (a Swiss funding office for developing countries) to pay for the research conducted by NTB and the creation of the fruit dryer itself (A. Lukacs, personal communication, March 19, 2015). The federal government, through the Swiss Agency for Development and Cooperation (SDC), also financed a great portion of the implementation of the fruit dryers in Burkina Faso (C. Huber, personal communication, March 18, 2015). Private companies in Switzerland aided financing the project as well.

Gebana Switzerland, for example, is a fair trade company that works with farmers and cooperatives in Africa (under the branch of Gebana Afrique), so they can get a fair share in the global economy. Gebana Afrique was established due to the high demand for dried organic and fair-trade mangoes in Europe. It helps countries like Burkina Faso by selling the farmers' goods (dried fruits, vegetables, etc.) to the external market and assisting them with the long-term preservation of their business. This is highly beneficial because Burkina Faso is one of the poorest countries in the world and this initiative relieves them from intermediary trade disadvantages (Gebana, n.d.). Ökozentrum and NTB gave the first fruit dryer to Gebana Afrique, and the company paid for the second one. Currently Gebana owns both dryers and pays for the workforce and land properties where the dryers are installed (C. Huber, personal communication, March 18, 2015). Ökozentrum hopes that in the future, the maintenance and operation of the fruit dryer will no longer require aid from outside organizations (Ökozentrum Langenbruck, 2012).

In Costa Rica, as explained in Section 2.3.2, Ökozentrum paid for the dryer, and the Swiss farmer Bruno paid for installing and operating it (workforce and land property). Bruno is still testing the dryer to decide the future of the implementation in Costa Rica (A. Lukacs, personal communication, March 19, 2015).

2.3 Implementation of the Low Cost Fruit

NTB's and Ökozentrum's main motivation for creating the low cost dryer was to implement the machine in developing countries to help local communities increase revenue. According to both institutions, the initial concern that a heat pump system would be too complicated for developing countries proved to be invalid, since these countries have had air conditioners for many years (Bertsch et al., 2015). The dryer was designed to have a simple operation and a low purchase price, being able to be built on site with local resources and maintained by local technicians. Developing countries have technicians who can fix air conditioners, so fixing the heat pump dryer in case of a malfunction was thought to not be a problem. After receiving training, NTB and Ökozentrum believed local farmers in the developing countries would be able to operate the dryer with no difficulties. However, as mentioned before, the transfer of know-how on how to assemble, operate, and maintain the fruit dryer has not been successfully achieved yet (Bertsch et al., 2015).

Before investing money on the design of a low cost heat pump fruit dryer, Akos Lukacs tested a standard heat pump dryer used in Europe, made of stainless steel, in Burkina Faso. The dryer did not operate as expected because of the extreme wet and warm weather. Therefore, NTB had to design a heat pump dryer that was robust and suitable for tropical climate conditions (A. Lukacs, personal communication, March 19, 2015). After its creation, several tests were conducted in Switzerland with a pilot unit to analyze the dryer's performance. In their final report, Akos Lukacs and Stefan Bertsch mentioned that all results were satisfying (Bertsch et al., 2015). In 2010, the first unit was implemented in Burkina Faso, and in 2014, one unit was established in Costa Rica (S. Bertsch, personal communication, January 29, 2015). One of NTB's goals now is to transfer this technological know-how to developing countries, and to possibly expand its dryer to other locations.

2.3.1 Burkina Faso

Burkina Faso is located in Africa, south of the Sahara Desert, as shown on Figure 6. The country has a total area of 274,200 m^2 and a population of 18.4 million (Central Intelligence Agency, 2013-2014). Due to its location, it is under a tropical climate, with warm and dry winters, and hot and wet summers. On average, it receives 8 hours of sunlight per day (Huber & Obermeyer, 2011).

Figure 6. Location of Burkina Faso (Wikimedia Commons, 2006a)

The country is heavily dependent on agriculture - about 90% of the population practice subsistence agriculture (Central Intelligence Agency, 2013-2014). As is common in developing countries, many fruits and vegetables end up spoiled, so drying fruits is a typical preservation method in Burkina Faso. The high levels of sun incidence year-round promotes the use of solar dryers. However, most of the harvest season in the country occurs during the rainy season (May, June and July), impeding the use of solar dryers (Bertsch et al., 2015). Due to this, the most common fruit dryer in the country is the gas dryer. As mentioned before, the gas drying method poses some problems, including fluctuating gas prices, and higher CO_2 emissions and operational costs in comparison to other dryers. In a gas dryer, fruits are in contact with the hot combustion gases. The temperature cannot be precisely controlled, so about 30% of the fruits have to be discarded because their first two layers end up discolored or burned (Bertsch et al., 2015).

In 2010, NTB and Ökozentrum implemented the first unit of its heat pump dryer in Burkina Faso. Since then, two additional dryers have been implemented (S. Bertsch, personal communication, January 29, 2015). According to the final report, Ökozentrum was not able to simulate the same environmental conditions of Burkina Faso in its lab tests in Switzerland, so the results had some minor deviations (Bertsch et al., 2015). The dried fruits had the same quality at the end of the process, but because of the high humidity of the country, less fruit could be dried than anticipated. Also, the system was disrupted sometimes due to high ambient pressure and power outages (up to 10 in a single day) (S. Bertsch, personal communication, January 29, 2015).

About 80% of the fruits produced in Burkina Faso are mangoes, so NTB and Ökozentrum focused on the drying of mangoes for this country (S. Bertsch, personal communication, January 29, 2015). The mangoes are dried in the heat pump at a constant temperature of 50º-60º C, compared to 100º C in a gas dryer (Bertsch et al., 2015). Due to this gentler process, the mangoes have a higher quality and are sold as "premium mangoes" in the export market. The amount of mangoes produced exceeds the needs of the local market. Thus, farmers in Burkina Faso directly benefit from the higher sales price when they export these fruits (Huber & Obermeyer, 2011).

Fruits exported to European markets need to meet certain quality standards and hygiene regulations. As mentioned in Section 2.2.3, the fair-trade company Gebana Afrique purchases the dried mangos from different cooperatives and associations and delivers them to customers around the world. The company, under the director David Heubi, works closely with the farmers to ensure fair trade conditions, and provides them with training and quality control (Gebana, n.d.). During one of his visits, Akos Lucaks also made a partnership with Swisscontact, a non-governmental organization (NGO) that promotes the sustainable economic development of developing countries (Bertsch et al., 2015). Swisscontact provides Vocational Education Training (VET) on refrigeration technology to local technicians in these countries, as well as lends out the necessary infrastructure and tools (Ökozentrum Langenbruck, 2012).

During the implementation process in Burkina Faso, Professor Bertsch mentioned that NTB and Ökozentrum faced some unexpected reactions from the local community (S. Bertsch, personal communication, January 29, 2015). Burkina Faso citizens are very proud, and thus hesitated to accept a fruit dryer with standards that would not be accepted in developed countries. They also wanted as little automation in the machine as possible. Finally, Ökozentrum wanted to store mangoes underground in cellars, due to their lower temperature. However, a large part of the population is religious, and some farmers refuse to dig into the ground more than a few feet because this is where dead people are buried (A. Lukacs, personal communication, March 19, 2015). Despite some initial unexpected reactions, the farmers quickly saw the benefits of the dryer, and the implementation was a success.

As explained in Section 2.2.2, a follow-up project is being evaluated in Burkina Faso for the possibility of independent energy generation from renewable energy sources. Since the country is located close to the Equator and receives a daily average of 8 hours of sunlight, photovoltaic cells were installed as a back-up power source. Biogas generators, powered by the climate-damaging methane gas emitted by rotten mangoes, also seem promising. The use of waste heat from cashew production is another possibility (Huber & Obermeyer, 2011). The shells of nuts have a high caloric value and can thus be used as an energy source (Bertsch et al., 2012). A system combining photovoltaic cells, a biogas generator, and a heat pump fruit dryer could lead to a CO_2-free production of mangoes (Bertsch et al., 2012).

2.3.2 Costa Rica

Costa Rica is located in Central America, south of Nicaragua and north of Panama, as shown in Figure 7. The country is 51,000 m^2 of land made up of 42 million people, with an average temperature of 25ºC and humidity between 60-90% (Nandwani, 2006).

Figure 7. Location of Costa Rica (Wikimedia Commons, 2006b)

Because of Costa Rica's tropical environment, solar power has potential in both the energy and fruit drying market, as shown in Table 1. Costa Rica receives an energy equivalent of 1300-1700 kWh/m^2 per year from the sun (Nandwani, 2006), compared to the United States that receives 600 kWh/m^2 (Renfrow, 2004), and to Switzerland that receives 1,100 kWh/m^2 Nordmann, 2013). Solar drying is the main drying method used in Costa Rica because it is cheap and easily constructible from local available materials (Ekechukwu, O.V.). However, solar dryers cannot operate during the rainy season, which coincides with the harvest season for most fruits. Heat pumps, on the other hand, are weather independent, making them favorable in this environment.

Table 1. Theoretical Potential Energy Sources is Costa Rica (Nadwani, 2006)

Sources	Potential	Utilized
Hydro	9155 MW	13%
Geothermal	900 MW	17%
Wind	500 MW	12%
Sun	$25x10^6$ MW	min.
Agriculture waste	101,859 metric T/yr	42%
Sugarcane waste	744,000 metric T/yr 100%	NA
Firewood	$25x10^6$metric T/yr	14%

In 2014, one of the low-cost heat pump fruit dryers was implemented in Costa Rica. As opposed to Burkina Faso, there was no major cultural or religious objection to the fruit dryer's implementation and operation in Costa Rica (S. Bertsch, personal communication, January 29, 2015). Akos Lukacs started the project to support a Swiss farmer, Bruno, who had the interest to work on organic agriculture, biodiversity, fair trade, and assistance to farmers in Costa Rica (A. Lukacs, personal communication, February 12, 2015).Upon implementation of the dryer in Finca Venecia, located in the Osa Peninsula, Akos Lukacs could test the heat pump technology with a large variety of tropical fruits. The main focus of the project was on the drying of cocoa because the best quality cocoa comes from South America (A. Lukacs, personal communication, March 19, 2015). Bruno's business involves drying cocoa to make chocolate, and then selling the chocolate to the local market in Costa Rica (A. Lukacs, personal communication, March 19, 2015). However, in the Southern zone of Costa Rica, most farmers do not have enough resources to restore the abandoned creole cocoa plantations of high potential (A. Lukacs, personal communication, February 12, 2015). Therefore, some of the present goals for Finca Venecia include motivating the farmers to take care of their cocoa plantations and selling the high-quality dried cocoa to the local market and to Switzerland (A. Lukacs, personal communication, February 12, 2015). Currently, Bruno is experimenting with the dryer to

Ökozentrum paid for the dryer (heat pump technology) and Bruno paid for implementing it (A. Lukacs, personal communication, March 19, 2015). Currently, Ökozentrum owns the dryer and Bruno is experimenting with it. After the trial period is over, he can send the dryer back to Ökozentrum if the operation is undesirable. If the operation is desirable, then he has the option of buying the dryer from Ökozentrum. Alternatively, if Bruno sends reports detailing the beneficial results of the dryer operation, he will not have to pay for the dryer since it will create positive publicity for Ökozentrum (A. Lukacs, personal communication, March 19, 2015).

2.3.3 Potential Implementation in Developed Countries

The low cost fruit dryer has only been sent to developing countries so far, but markets for the dryer may also exist in developed countries. However, the fruit dryer developed by NTB and Ökozentrum is primarily constructed out of wood, which does not comply with various health and safety restrictions in developed countries. If NTB develops a fruit dryer that is acceptable in countries with more rigorous health and safety standards, it is likely that the implementation would be successful due to the growing demand for dried fruits in developed countries (CBI, 2008). Even if the dryer did meet health regulations in developed countries, there would still be certain social restrictions governing where the dryer could be sent. A dryer could only be sent to a new location if the purpose of the implementation is to benefit local communities rather than bring profit to organizations.

Europe is a net importer of dried fruit, although several countries within the European Union (EU) are major producers of dried fruits and production rates have been increasing in the past decade. The EU countries in total produced approximately 1.29 million tons of dried fruit in 2002, which increased to approximately 1.72 million tons in 2006. In Europe, Italy, Spain and the United Kingdom are the three largest dried fruit markets (CBI, 2008). Due to the promotion of health benefits from dried fruits, the market for these products in developed countries is expected to continue increasing in the coming years. Most dried fruits are imported from developing countries, but developed countries started to produce dried fruit as well. Some developing countries see the increased production of dried fruit in developed countries as a threat to their share of the market. However, the production of dried fruit in both types of countries can serve to create trade channels that benefit both sides of the market (CBI, 2008).

2.4 Considerations Before Implementing a Fruit Dryer

Before implementing any fruit dryer in a new location, it is important to confirm that the technology is appropriate for the community. The notion of 'appropriate technology' has been studied by scholars for years, and some of its characteristics are summarized below (Hazeltine & Bull, 2003; Darrow & Saxenian, 1975):

- It fixes a problem that is of relevance to the community.
- It offers opportunities and improvements to the local community.
- It can be understood and operated by the local community.
- It is sturdy and durable.
- It requires low capital costs.
- It can be built with locally available materials.
- It is environmentally sustainable.

Based on these characteristics, an implementation can only be effective if the fruit dryer is well received by the local community. Several aspects influence the reactions of the local people to technology transfer, including cultural differences, the nature of the technology (e.g., does it displace labor?), and the benefits (financial, social, environmental, etc.) of the implementation to the community. Hence, in the planning stage, understanding the culture and needs of the people in the new locations is a determinant early step for implementing an appropriate technology. Additionally, any implementer of a fruit dryer needs to evaluate the price and availability of fruits, total costs, market interest, and labor requirements associated with the implementation.

2.4.1 Price and Availability of Fruits

In 1996, the Food and Agriculture Organization of the United Nations (FAO) conducted a study in Uganda regarding the implementation of a solar fruit dryer in rural areas (Anstee et al., 1996). Even though NTB's dryer does not use the traditional solar method, most considerations presented in the FAO's report are valid for our project. One of them relates to the price and availability of fruits at the desired location.

The experience in Uganda concluded that the international market value for dried fruits is substantially higher than for dried vegetables. Mangoes are a common choice partly because they are a rich source of vitamin A, which reduces the likelihood of child blindness. In most cases, vegetables are only dried when the dryer is not being used for fruits. Fruits are chosen based primarily on price and availability. For a solar dryer, FAO calculated that fruit costs account for 60% of the total production cost. The price paid for a high-quality fruit, with the desired maturity, needs to be low enough to make the final product profitable to the farmer - and thus the drying method justifiable. The best way to compare fruit prices is not by comparing their unit value, but rather by comparing how much needs to be spent on the different options of fresh fruit to yield one kilogram of dried fruit (Anstee et al., 1996). For example, an apple may cost $1 and a banana may cost $2, but that does not mean the banana is a more expensive option. If one fresh apple yields 200g of dried apples, while one fresh banana yields 600g of dried bananas, then you will need 3 apples to produce 600g, or $3. So, in fact, the banana is cheaper than the apple.

Fruit availability is another major factor to be accounted for. Determining what fruits are available most of the year at the desired location is a significant step. Sometimes, it is more profitable to dry different fruits in different seasons. Under harsher weather conditions, tomatoes and mushrooms tend to be easier to dry than mangoes, pineapples and bananas (Anstee et al., 1996). It is also relevant to know how many farmers grow the fruit locally and how far away these producers are located. Ideally, the drier should be installed next to the fields, so that transportation costs are minimized.

2.4.2 Costs

Cost analysis is important when understanding the finances associated with implementing technology in a new location. The price of the NTB's and Ökozentrum's dryer itself, though low compared to commercial companies, is still higher than most farmers can afford. Building and installing one system costs €3000-€3500 (about $3180-$3700) (Bertsch et. al., 2012), but this value is unattainable for a farmer that makes $180 per year (TechnoServe 2013). Therefore, small businesses or non-profit organizations are needed to set up these dryers (Chua, 2003). Furthermore, once implemented, a business needs to determine the energy prices necessary to power the dryer. For example, solar energy is cheap using freely available sunlight rather than conventional fuels to dry products. Gasoline energy is not renewable, and with the fluctuating price of gas, can lead to much higher operating costs (Chua, 2003).

Often the fresh fruit is relatively cheap, but the transportation costs can be high. Optimally, the dryer should be located nearest to the fields for a quick transfer from harvest to drying. In addition to installing the fruit dryer next to the producers, it is beneficial to place it close to the point of sale. If the trading company is far away, the transportation costs are higher, and more dried fruits will be needed to be taken at once to make the overall business profitable (Anstee et al., 1996).

Another factor to consider is the off-season for farming. The peak season for mangoes in Costa Rica is March and April, so operations during the off-season will be less profitable because the fruit dryer will have no mangoes to process (Central American Export, 2014). One way around this is having a broad range of fruits available that can be grown during more months of the year.

Lastly, the price of the labor force has to be addressed. Companies like Global Exchange will pay farmers a minimum of $1.26/pound of coffee in Ethiopia, which is three times as much income as the average coffee producer would earn (Valkila, 2010). Labor force is among the least expensive portion of cost for implementation in developing countries, however it all depends on the average economy in that country.

2.4.3 Market Interest

Before implementing the fruit dryer in a new location and selecting a potential fruit, a study must be conducted to determine the local market interest in the different dried fruits. In some places, people prefer consuming seasonal fresh fruits rather than dried fruits. In Burkina Faso, the production of dried mangoes exceeds the local interest, creating a surplus that can be exported. However, in Samoa, where there is currently a surplus of fresh papaya, a study conducted by the University of South Pacific concluded that the Samoan market would be interested in dried papayas, making exportation unnecessary (Buenz & Fuatai, 2007).

In 2008, research institutes from Poland, Netherlands and France conducted a study to determine the frequency of dried fruit consumption in these countries (Jesionkowska, Konopacka, Plocharski, Sijtsema, & Simoneaux, 2008). An online survey was sent out to 1092 respondents (440 Dutch, 240 French, and 412 Polish). The results are shown in Figure 8. Frequency of dried fruit consumption among Dutch, French, and Polish (Jesionkowska et al., 2008). In the Netherlands, 58% of the respondents declared that they never consume dried fruits. In the three countries, less than 10% of the respondents consume dried fruits on a daily basis. No definite conclusions can be drawn based solely on percentages, but these numbers may signal that the market interest in dried fruits at these locations is not substantial.

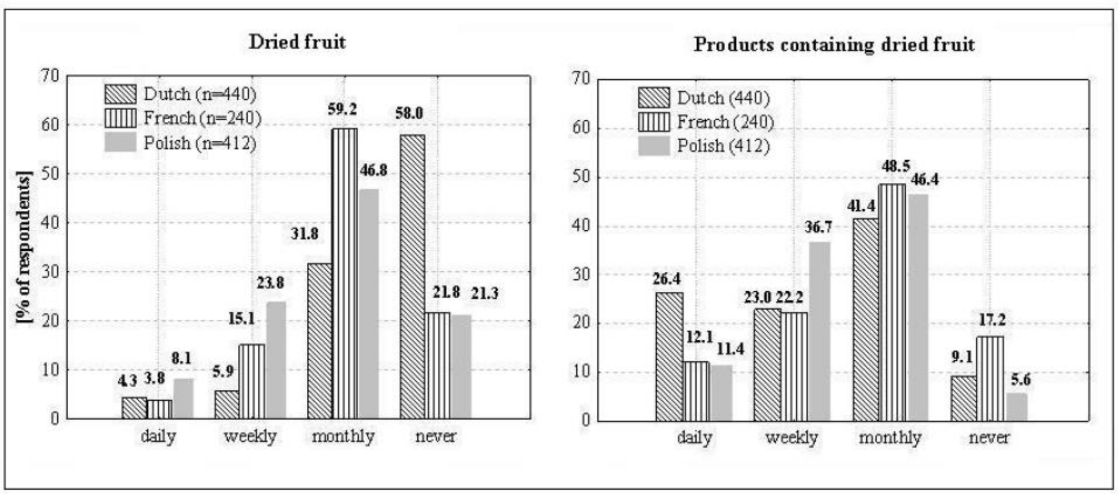

Figure 8. Frequency of dried fruit consumption among Dutch, French, and Polish (Jesionkowska et al., 2008).

If the local demand is small, the surplus can be sold to different cities and/or countries. In Burkina Faso, as mentioned in Section 2.3.3, the fair-trade company Gebana Afrique buys dried fruits from small-scale farmers and distributes them to the external market, mainly Europe. Similarly, in Uganda, the Austria Development Agency, an Austrian-based NGO, supports farmers in the implementation of solar dryers and sells their dried fruits to the Austrian market (Kalyango, 2009).Storing the dried fruits for longer periods can deteriorate their quality (Anstee et al., 1996). Therefore, regardless of the final consumer, it is essential to determine who will buy the dried fruits on a monthly basis before the implementation.

Meeting the regulations and quality standards of the country where the dryer is to be implemented is a crucial early step in the planning process. For example, in Europe there is a promising market for dried fruits (CBI, 2008), but there are sanitation regulations that prohibit the use of wood as the building material for a fruit dryer (S. Bertsch, personal communication, January

29, 2015). Strict regulations can quickly eliminate countries from consideration for this project, so before researching market interest, it is important to analyze the regulations and standards specific to each country.

2.4.4 Labor

Labor requirements also play a role when implementing technology in a new location. Factors to consider are the required knowledge and skill level of the workers, as well as the on-site opportunities available for training them to operate the machine. The labor required for the operation of the fruit dryer consists of people to purchase the fresh fruit, prepare the fruit for drying, load and unload the fruit into the dryer, package the fruit, and lastly, sell the fruit (Anstee et al., 1996). In addition, the technology requires a management system in place for supervision. For all of these positions, though some jobs may be simpler than others, specialized training is needed.

The fruit dryer is straightforward and easy to use, allowing for a broader user range that includes uneducated people of the agricultural field. Although the machine is easy to operate, assessing the necessary education levels can dictate the level of training required. For example, an individual who is illiterate would require additional visual and verbal training compared to an individual that is not. This consideration is key in determining what to include in training sessions when first implementing this technology.

NTB's and Ökozentrum's heat pump dryer must be implemented in a location where the labor force in the agriculture sector is plentiful. To be well accepted, as explained in the next section, the dryer cannot cause labor displacement. Therefore, the presence of local partners that can provide training to the workers (similar to Swisscontact in Burkina Faso), so that automation does not become a problem, is fundamental when choosing a new site. Also, looking for local technicians in the field of air-conditioning repair could be beneficial because the heat pump dryer operates like an air conditioner, as discussed in Section 2.2.1.

2.4.5 Reactions to Technology Transfer

One of the key elements of an appropriate technology is that it is introduced in a way to be well received, not forced. Thus, when selecting a location to implement the fruit dryer, reactions of the population to technology transfer need to be considered. Dr. Lin and Professor Berg, from Rensselaer Polytechnic Institute, conducted an empirical study on Taiwanese manufacturing companies and confirmed three common factors that impact the effectiveness of technology transfer (Figure 9): the nature of the technology, the new location's previous international experiences, and cultural differences between the technology provider and receiver (Lin & Berg, 2001).

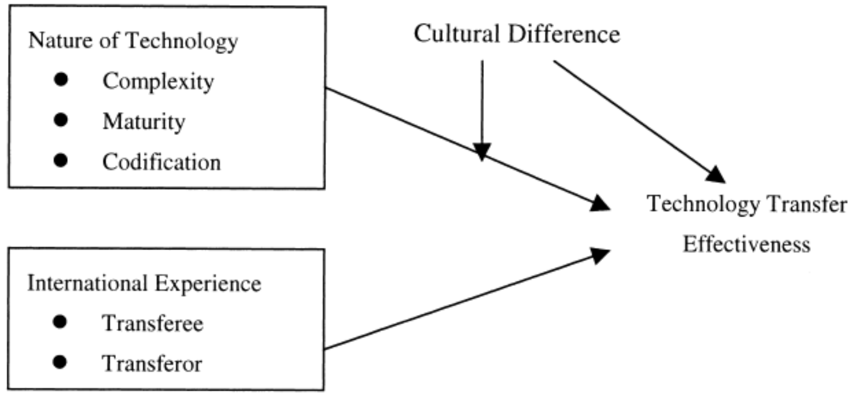

Figure 9. Technology transfer effectiveness (Lin & Berg, 2001)

To be well accepted, the nature of technology should not be complex. Farmers should be able to operate the dryer with ease and receive a higher profit for the dried fruits than before (Brady, 1983). It is also important for the fruit dryer to be a good fit for the community and to contribute to fixing existing problems. Many technological implementations fail to achieve that. As an example, in the 1970's, mechanized rice hullers were implemented in Java, an island in Indonesia, to increase rice production and boost the economy (Cain, 1979). At that time, more than 80% of the Java population resided in rural areas, and the economic conditions of the island were not satisfactory. With the hullers, however, more than 1.2 million people ended up losing their jobs due to automation (Cain, 1979). The technology increased rice production and efficiency, but did not solve the region's problem of unemployment; it actually worsened it, making its implementation inappropriate. In Burkina Faso, as mentioned in Section 2.3.1, one of the reasons the farmers initially hesitated was their concern with automation as well (S. Bertsch, personal communication, January 29, 2015). To avoid this type of issue, both farmers and implementers need to be educated about the technology and the context in which it is being implemented. On the one hand, local promoters are a key resource to educate the implementers (Cain, 1979). They are native people who understand the local community and its needs, and work as consultants to make sure the technology implemented is appropriate to the place. On the other hand, local institutions' forums and symposiums are effective resources to explain the fruit dryer to farmers when they are not able to recognize its importance and validity (Qiang, Yuanhong, & Gould, 2012). In conclusion, it is fundamental to choose a location in which implementing the low cost fruit dryer will fit the needs of the community and enhance its economic conditions.

The effectiveness of technology transfer is usually higher for countries with previous international experiences (Lin & Berg, 2001). These locations often have higher confidence in modernization and international cooperation due to past successful interactions, and thus the population reacts better to new foreign technologies. In communist countries like China, commonly the government leads technology transfer. For example, in the early 1990's, the Chinese government initiated a project in Gansu for sustainable rainwater harvest, which was very well received by the population (Qiang et al., 2012). For NTB and Ökozentrum, it is more challenging to introduce the fruit dryer into countries where the government has absolute control because external institutions' actions are restricted. Thus, when choosing a new location, countries with previous international experience that do not restrict external initiatives will likely allow for an easier implementation.

Among all the considerations referenced, none affects people's reactions to technology transfer as significantly as cultural differences. As mentioned in Section 2.3.1, some farmers in

Burkina Faso refused to store mangoes underground in cellars due to religious reasons. They believe that the place where dead people are buried is sacred and should not be disturbed. (A. Lukacs, personal communication, March 19, 2015). The implementation team for the rainwater harvesting project in China mentioned above also faced some cultural obstacles. In the attempt to prevent pollution by livestock, the team asked householders to build the tank inside their patios. However, many householders refused to initially participate in the project because they held a superstition that their family could suffer a misfortune if the earth in the patio was disturbed (Qiang et al., 2012). Thoroughly analyzing the culture, religion, and beliefs of each possible new location is a major step in the selection process. The fruit dryer will only operate successfully in countries where it receives support from the local community.

2.5 Summary

Technology transfer is a complicated process. Different communities have distinct cultures and motivations, and there are many considerations to take into account when designing technology to be implemented. A successful technology transfer benefits the local communities by fixing one or more of their problems, offering them new opportunities, and/or improving their standard of living. To gain autonomy in the implementation process, local communities need to understand and be able to operate the machine by themselves. Furthermore, the machine should ideally be built with materials available on-site.

More specific considerations for a successful technology transfer include the labor requirements necessary for the machine, the costs involved with the implementation process, the market interest on the final product, and the reactions of the local communities to technology transfer. Organizations leading the implementation process should respect the cultural and religious aspects of the locations and carry out market research beforehand to ensure that the machine has enough economic feasibility.

Every location exhibits a diverse range of challenges, and this section has addressed obstacles faced by NTB and Ökozentrum in Burkina Faso and Costa Rica. The information provided in this section helped to clarify the issues involved with implementing fruit dryers in developing countries and outlined important considerations to take into account during future implementations.

CHAPTER 3: Methodology

The primary goal of this project was to aid Ökozentrum and NTB-Interstate University of Applied Science to broaden the impact of their fruit dryer in developing countries. This included not only improving the fruit drying operation as a whole, but also facilitating its transfer to different locations. To accomplish this goal, we collaborated with NTB to understand the fruit dryer's previous implementations and optimize the technology transfer process for future expansions.
We worked in Switzerland from March 16th to May 5th at NTB in Buchs, St. Gallen. The project was divided into the following objectives:

1. Design an analytical tool for assessing the implementation of fruit dryers.
2. Apply the analytical tool to the low-cost heat pump fruit dryer.
3. Improve the operation of the low-cost heat pump fruit dryer and facilitate its expansion to new locations.

These objectives were broken down in a series of methods, depicted in To find ways in which we could facilitate the expansion of the fruit dryers to new locations, the effects of the fruit dryer implementation on the communities in Burkina Faso and Costa Rica were examined. Trying to find out whether or not the fruit dryers were benefiting these communities was a complex task that required several considerations to be taken into account (addressed in our analytical tool in Section 3.1). Due to time and travel restrictions, we could not conduct a full analysis of both implementations (i.e., not all considerations from the analytical tool could be addressed). It was not possible for us to contact the actual users of the fruit dryer, but interviewing NTB's major partners and those who have been involved with the fruit dryer project was a crucial step in finding out some aspects of the implementations that were working and some areas that needed to be improved. After gathering enough information to illuminate these areas of improvement, it was then possible to explore methods of enhancing the fruit dryer operation and improving the technology transfer process for future implementations.

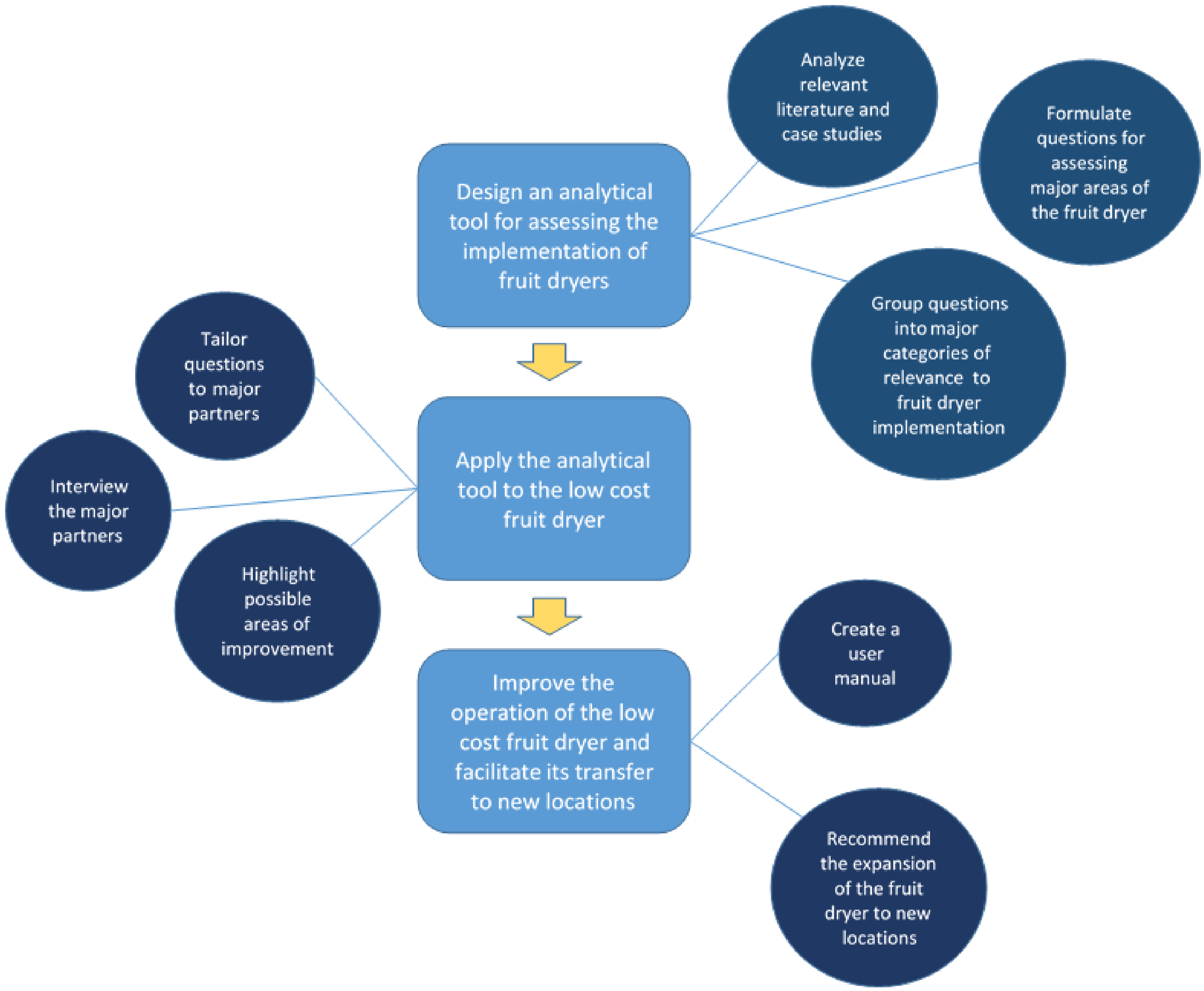

Figure 10 on the next page. The timeline to achieve our objectives is shown in Figure 11.

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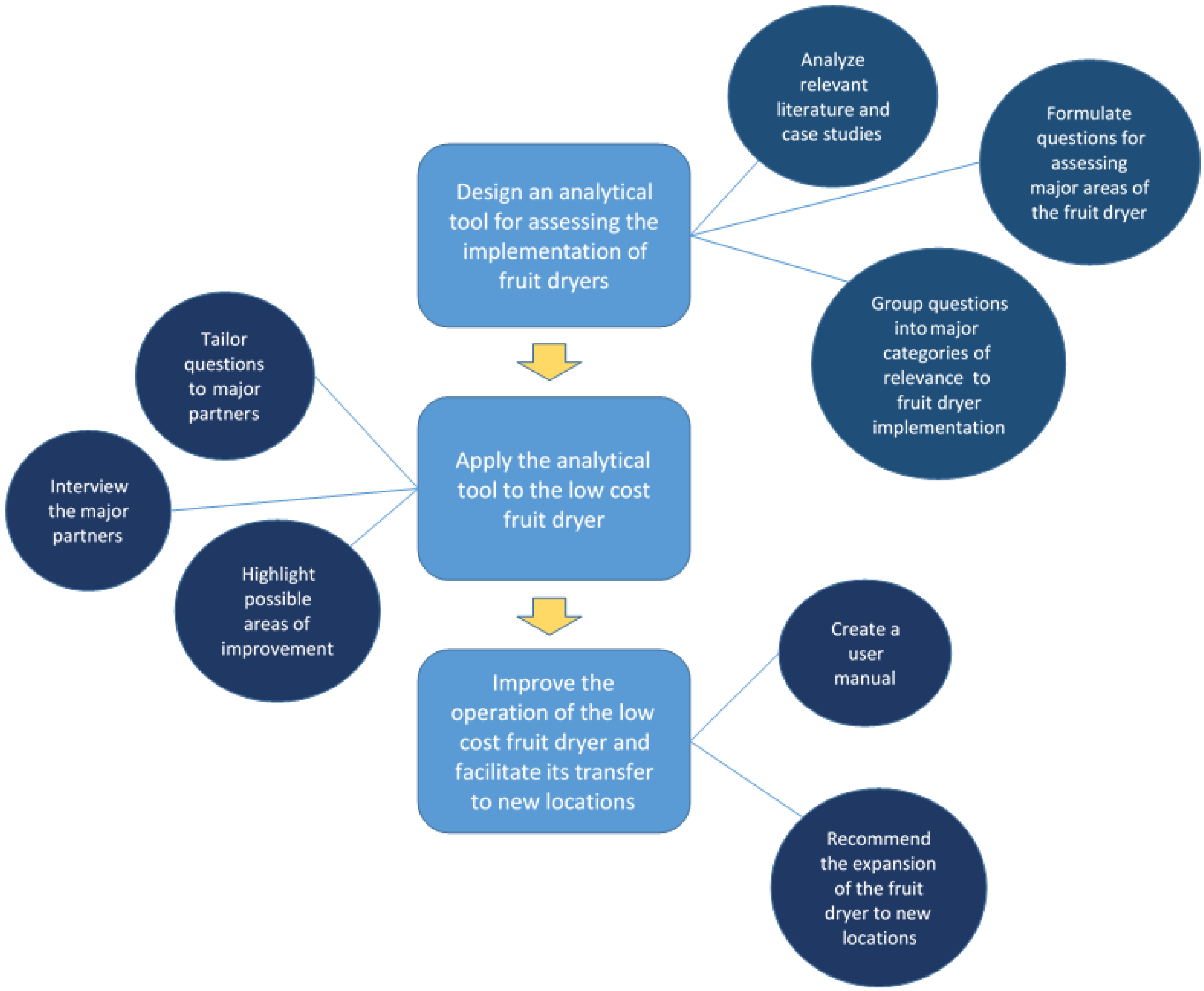

Figure 10. Methodology strategy

Project Goal	Steps to take	Weeks							
		Prep	1	2	3	4	5	6	7
Design an analytical tool for assessing the implementation of fruit dryers	Analyze relevant literature and case studies	■							
	Formulate questions for assessing major areas of the fruit dryer	■							
	Group questions into major categories of relevance to fruit dryer implementation	■							
Apply analytical tool to our project	Tailor questions to major partners	■	■						
	Interview the major partners	■	■	■					
	Highlight possible areas of improvement	■	■	■	■	■	■		
Improve the operation of the low cost fruit dryer and facilitate its transfer to new locations	Create a user manual			■	■	■	■	■	■
	Recommend the expansion of the fruit dryer to new locations		■	■	■				

Figure 11. Project timeline

3.1 Design an Analytical Tool for Assessing the Implementation of Fruit Dryers

Assessing the effects of the fruit dryer on the communities in developing countries is a critical step before assuming that the system is ready to be shipped elsewhere. In the 2011 Engineers Without Borders (EWB) Canada Failure Report, Mike Klassen, a staff member who worked with agricultural communities in Ghana, affirmed that “we regularly make assumptions about the way things work without getting into the field to challenge our preconceived notions and without fully understanding the existing system before trying to change it.” (Klassen, 2011). One way to fully understand the existing system and prevent erroneous assumptions is by speaking with the stakeholders directly. As an initial step for our project, we created an analytical tool encompassing questions to investigate any fruit dryer implementation. This tool could then be used to interview stakeholders.

To design our analytical tool, we reviewed literature and case studies to form a basis of questions to consider. Our questions were primarily based on the studies of the Food and Agriculture Organization of the United Nations (FAO), United Nations Industrial Development Organization (UNIDO), Barrett Hazeltine and Christopher Bull, Jim Price, PEI, and David Teece. The FAO published an extensive set of questions after conducting a study in Uganda regarding the implementation of a solar fruit dryer in rural areas (Anstee et. al, 1996). FAO's questions address the issues of fruit price and availability, labor, costs, and other considerations. The UNIDO created a technology manual for small-scale fruit and vegetable processing and products, including production methods, equipment and quality assurance practices (Fellows, 2004). Barrett Hazeltine and Christopher Bull wrote the book “Field Guide to Appropriate Technology,” a hands-on-guide for people working in less developed communities (Hazeltine & Bull, 2003). Jim Price, a serial entrepreneur and business educator, wrote an article entitled "12 Essential Questions You Need to Ask Before Launching a Big New Idea" (Price, Jan 22, 2013). PEI, a technology consultancy and service provider, published "10 Less Obvious Questions to Ask Before Implementing a New Technology or Changing your IT Strategy"(Christensen, 2012). Lastly, David J. Teece, author of 200 published articles and books on economics and business, wrote "Business Models, Business Strategy and Innovation" (Teece, 2010).

Our analytical tool was based on questions from the publications mentioned above as well as the considerations specified in the Background Section 2.4 and questions created by our group. The analytical tool was divided into seven major categories: price and availability of fruit, social and cultural considerations, labor requirements, costs, partners, market interest, and fruit dryer mechanics and operations. This tool (Table 3) is located in Section 4.1.

3.2 Apply the Analytical Tool to the Low Cost Heat Pump Fruit Dryer

There are numerous partners and stakeholders associated with Ökozentrum's and NTB's fruit dryer. To find possible areas for future expansion of this project, each group's involvement had to be understood. A stakeholder analysis was a useful tool for illuminating areas of improvement in the operation of the fruit dryer and in the process of transferring it to new locations. As a tool, the stakeholder analysis not only identifies the groups involved in a business, but also sorts them according to their roles (Degeorge, 2010). For our project, the analysis was carried out using interview plans based on the analytical tool created in Section 3.1 and presented in Section 4.1, but tailored to each specific stakeholder. Because of limited ability and resources to contact individuals living in the developing countries, our analysis focused on the partners involved rather than all the groups affected by the fruit dryer. Relevant partners listed by Stefan Bertsch are outlined in Table 2 with their description/involvement in the project.

This section focused on discussing the roles of various partners involved in this project, and outlined interview questions for each partner that was contacted. The interview plans are located in Appendix A. Out of all the partners listed in Table 2, we interviewed only Stefan Bertsch, Christian Huber (Ökozentrum), and Ákos Lukacs. Some partners were not available for interviews, and these three were the major individuals involved with the creation and implementations of the low cost fruit dryer. By interviewing these three partners, we obtained enough information to create a plan of action. This information included the motives for creating a low-cost heat pump fruit dryer, the process that led to its creation, the story behind both implementations, suggestions for areas of improvement in the operations and transfer of the dryer, and possible locations for future expansions. With the information gathered from each interview, we highlighted areas of improvement to be addressed and new locations to be considered (see Section 3.3).

Although the interviews primarily took place in Switzerland, the process began in the United States. Several partners were contacted through email, and some questions were answered beforehand. For all interview plans, information provided that hinted at possible areas of improvement was marked orange, as can be seen in the interviews located in Appendix A.

Table 2. Description and involvement of partners

Company/Person	Description/Involvement
NTB (Stefan Bertsch)	Stefan Bertsch, our liaison, leads the Institute of Energy Systems (IES) of NTB, and works with photovoltaics, refrigeration equipment, power electronics, and heat pumps. In 2008, Stefan Bertsch collaborated with Akos Lukacs to create the low-cost fruit dryer. Our sponsor's mission in this project is to create jobs and improve infrastructure in developing countries using environmentally friendly and sustainable technology (S. Bertsch, personal communication, February 9, 2015).
Akos Lukacs	Akos Lukacs is a mechanical engineer who has worked on projects in the field of developmental cooperation in the ecological center Ökozentrum for the past six years. He worked with Stefan Bertsch to create the fruit dryer in 2008 and actively participated in the Burkina Faso and Costa Rica implementations. Now, Akos Lukacs works privately from Ökozentrum on the further implementation of the fruit dryer in new locations, possibly Ecuador (Ökozentrum Langenbruck, 2012).
Ökozentrum (Christian Huber)	Ökozentrum is a research NGO established in 1980 in the fields of renewable energy and development of innovative technologies for environmental and climate protection. They educate other companies and individuals in energy conservation and sustainable consumption. Together with NTB, they designed the fruit dryer and were involved in both implementations (Ökozentrum, 2015). Christian Huber is the new person at Ökozentrum responsible for developing countries.
Gebana Afrique (David Heubi)	Gebana Afrique is a fair trade company that purchases dried mangoes and cashews from different cooperatives and associations in Africa and delivers them to customers around the world. The company, under the director David Heubi, owns the dryers in Burkina Faso and works closely with the farmers to ensure fair trade conditions, while providing them with training and quality control (Gebana, n.d.).
Swisscontact	Swisscontact is an NGO that promotes the sustainable economic growth of developing countries (Garrison, Lukacs, & Bertsch, 2015). Swisscontact provides Vocational Education Training (VET) on refrigeration technology to local technicians in Burkina Faso, as well as lends out the necessary infrastructure and tools (Ökozentrum Langenbruck, 2012).
SNIS Swiss Network for International Studies	SNIS promotes academic research in international studies. It is a funding agency supported by the State Secretariat for Education and Research of the Swiss Confederation, and the Department of Public Instruction of the Republic and Canton of Geneva. SNIS has an extensive know-how in international projects, and thus has created important partnerships with Swiss and foreign academic institutions, international organizations, NGO's, and private companies (Swiss Network for International Studies, n.d.). The agency has connections with important individuals/companies, like Mandu dos Santos.

Company/Person	Description/Involvement
Mandu dos Santos	Mandu dos Santos Pinto is the CEO of the architecture and consulting company Mandu. He has initiated many sustainable and innovative projects in Africa, working together with African and Swiss research institutes (Dos Santos Pinto, 2013). Mandu is a valuable source of information to understand the potential obstacles and opportunities encountered when transferring technology from a developed country to a developing one.
Isomet Burkina Faso	Isomet was founded in 1997 with the goal to contribute to the development of Burkina Faso by providing domestic energy solutions in the form of solar cooking devices (Ilboudo, 2012).
Myclimate Schweiz	Created in 2002 from a joint project by students and professors at the ETH Zurich, Myclimate Schweiz has grown into a professionally managed and internationally focused climate protection foundation. Myclimate's goal is for worldwide climate protection through education, consulting, and project-orientated reduction of CO_2 emissions (Fontana, 2015).
Racine Kambwole	Racine Kambwole is a representative of PNUE (United Nations Environment Program) and PNUD (United Nations Development Program) in Burkina Faso, and the national coordinator of the Ozone Office in Burkina Faso (Belemsobgo, 2014). He is a refrigeration expert, knowledgeable about the fruit dryer mechanics and the implementation process in Burkina Faso.
REPIC Renewable Energy and Energy Efficiency Promotion in International Cooperation	REPIC is a Swiss funding office for developing countries. Its goal is to provide information and renewable energy technology to developing countries. The company funded the initial research for the project and was involved in the implementation of fruit dryers in Burkina Faso (Nowak, 2015). Currently, Repic is funding a study, in coalition with Ökozentrum, for expanding the fruit dryer within Burkina Faso.

Our interview questions have been tailored to suit each partner due to their expertise in specific areas of the project. We have interviewed Stefan Bertsch, our liaison, several times since the beginning of our preparation term. Most of the interview questions regarded technical aspects of the fruit dryer, NTB University itself and their role in the project, partners to contact, and improvements that could be made to the dryer. We interviewed Christian Huber so that we could gain a better understanding of the role of Ökozentrum in the project. Most of the interview questions regarded cultural and economic aspects of the implementation in Burkina Faso, labor requirements, funding, and possible areas of improvement in the fruit dryer technology and operations. Finally, Akos Lukacs was a major resource who gave us information about the motivation behind the project, how the project began, funding, social and cultural considerations from both implementations, all aspects of the implementation in Costa Rica, and suggestions for improving the technology transfer process in future expansions.

3.3 Improve the Operation of the Low Cost Fruit Dryer and Facilitate Its Transfer to New Locations

After gathering information from background research and interviews with major partners, we determined various areas of improvement in the operation and technology transfer process of the low cost fruit dryer. By creating an analytical tool and applying it to the fruit dryer, we chose (together with NTB and Ökozentrum) attainable and effective improvement areas that could aid future implementation processes. We considered improvement to be any modification to the drying system or operation that increases its performance and/or efficiency, promotes a better management of resources, facilitate the process of technology transfer, reduce costs, and allow users in developing countries to more independently evaluate, build, modify, operate, and repair the dryer. In addition, we discussed with the partners possible future expansions for the fruit dryer and investigated countries where new implementations could take place. The sections below outline the methods that we used to produce our deliverables, presented in Chapter 4.

3.3.1 Build the Fruit Dryer and Create a User Manual

As mentioned before, the know-how regarding the fruit dryer assembly, operation, and maintenance has not yet been successfully transferred to local people in the developing countries, making them dependent on NTB and Ökozentrum. After talking to major stakeholders, we concluded that creating a user manual would be the most effective way of improving the technology transfer process. By providing the necessary instructions and information to local organizations in new locations, a user manual aims to give autonomy to the communities in these countries. It also allows the fruit dryer to be implemented in locations where shipping a finished dryer is not possible. Providing assembly and operation instructions is crucial in expanding the range of countries in which the fruit dryer can be implemented, since countries can have extremely high import taxes or other restrictions that would prohibit a complete dryer from being shipped there. The user manual breaks down the assembly and operation processes into simple steps that allow the dryer to be assembled and activated on-site, ideally without the aid of NTB, Ökozentrum, or other outside organizations. We designed the manual under the assumption that carpenters in the developing countries will build the chambers and pallets, electricians will assemble the electrical system, and air conditioning technicians will assemble the heat pump system. Thus, we described all steps in detail, but expected a certain level of common knowledge from these professionals.

To create the user manual, we first worked with technicians and engineers at NTB to build the low-cost heat pump fruit dryer from scratch. The outcome, a fruit dryer with modifications, is explained in Section 4.2. During the building process, photographs were taken of each step to document the assembly details. CAD models and drawings for the dryer were created to supplement photographs and add clarity to main assembly procedures. After construction, the operation of the fruit dryer was similarly documented using photographs that depict the layout of fruit on the pallets and how to operate the fruit dryer itself. Sections 4.3 includes an explanation of the different chapters of the user manual, as well as a link to an online PDF of the manual.

3.3.2 Recommend the Expansion of the Fruit Dryer to New Locations

After designing the analytical tool and interviewing the major partners involved in the creation and implementations of the low cost fruit dryer, we understood the importance of taking into account many considerations before an implementation can take place. The low cost fruit dryer is a technology with a "value system". It was not designed to bring profit to the organizations, but rather to benefit local communities in developing countries (see Section 4.4). Respecting the culture and motivations of these communities has always been a high priority for NTB, Akos Lukacs and Ökozentrum. Before recommending the expansion of the fruit dryer to new locations, we needed to verify if the organizations leading the implementations were aligned with the motives and goals of the project. It was also necessary to confirm that the local communities would accept and understand the technology, benefit from the dryer, and have their culture and beliefs respected. Due to travel restrictions, we could not talk to the actual communities, so all information we obtained was based on the perspective of the leading organizations.

When we interviewed Stefan Bertsch, he informed us about a German man named Christoph Günner, who is currently working to establish better fruit dryers in Bali, Indonesia, and is interested in working with NTB and Ökozentrum (S. Bertsch, personal communication, March 6, 2015). We conducted an interview with Christoph Günner to understand what his goals for the implementation were and if we should recommend the expansion of the fruit dryer to Indonesia or not. The interview is located in Appendix A.4 and our findings are located in Section 4.7.

Ecuador is another country in which the dryer will likely be implemented. Akos Lukacs went to Ecuador and verified that gas prices are rapidly increasing there (A. Lukacs, personal communication, March 19, 2015). He visited a foundation called Salinerito, which currently uses gas dryers made of stainless steel to dry and export mushrooms to Switzerland. He intends to go to Ecuador next year to implement the low-cost heat pump dryer, and is currently thinking about the best way to get the dryer there. He pitched the idea of giving the workers the plans to build the basic chamber of the dryer before he would arrive, after which he would only need to install the heat pump when he gets there (A. Lukacs, personal communication, March 19, 2015). This showed a step toward greater independence of the communities in developing countries, which was one of our major motivations for the creation of a user manual.

CHAPTER 4: Outcomes and Findings

This section outlines our major outcomes and findings during the seven weeks we worked at NTB. After all the interviews we conducted, we concluded that the best way for us to improve the technology transfer process would be to design a technology transfer analytical tool and to create a user manual for assembling and operating the fruit dryer. Most of our findings are related to the challenges we came across when building the dryer and writing the user manual, and what was learned from overcoming these challenges. This chapter begins by presenting our major outcomes: the analytical tool (4.1), the fruit dryer with recent modifications (4.2), and the user manual (4.3). Then, it describes the lessons we learned when building the dryer (4.4), followed by the lessons we learned when writing the user manual (4.5). Next, the section describes our findings regarding the fruit dryer itself (4.6). Finally, the section describes our findings regarding expanding the dryer to new locations (4.7).

4.1 Outcome #1: Analytical Tool

As explained in Section 3.1, we created an analytical tool to evaluate the implementation of fruit dryers in general. The tool is a compilation of questions that were broken down into seven major categories: price and availability of fruit, social and cultural considerations, labor requirements, costs, partners, market interest, and fruit dryer mechanics and operations. Even though the tool was designed for fruit dryers, it is a convenient resource that can be tailored to any technology. Several organizations involved in transferring technology to other locations can benefit from the applications of this tool. The considerations presented can be used to evaluate the successes and issues of a current implementation and/or to assess the feasibility of expanding technology to a new location. For all implementations, current and future, the analytical tool can be used to check if the goals of the leading organization are aligned with the needs and motivations of the communities receiving the technology. Table 3 depicts the analytical tool.

Due to our time constraint and goals for the project, we only addressed in the analytical tool some of the concerns involved with technology transfer. One value of the tool is to allow a careful assessment of the considerations currently listed to determine whether or not the most effective questions are being asked and what questions are missing. Even if the questions currently included in the tool are perfectly relevant, there is still room for additional questions that address issues that were previously unexplored. For example, the costs section of the analytical tool was not fully explored since there are many different factors that can affect the finances of a fruit dryer or an implementation process. A more detailed research would be required, and using a cost analysis tool to examine this topic is likely more efficient. In conclusion, the analytical tool is a dynamic resource that needs to be continuously updated in order to become increasingly effective in facilitating technology transfer processes.

Table 3. Analytical tool

A. <u>Price and Availability of Fruits</u> The price and availability of fruit can depend on the growing season, the distance from the farms to the fruit dryer, and the country's agricultural capabilities as a whole. These questions are important to consider in order to ensure that the location in question has the necessary agricultural resources and capabilities to make a fruit drying operation worthwhile.	1. Are there locally grown fruits and vegetables that can be dried? 2. What fruits are available most of the year? o During what months? 3. How much do the prices of these crops vary during the year? 4. What types of spoilage can affect the fruit processing? 5. What is the price of the locally grown fruits? 6. What is the international price of the dried fruit being considered? 7. How far away are the sources of fruit from the dryer? 8. Can local farmers be contracted to grow the crops?
B. <u>Social and Cultural Considerations</u> Differences in cultural and religious views can lead to unexpected obstacles. Acceptance of new construction and technology is not guaranteed, and a lack of prior research can significantly affect the success of a project.	1. Is there a foreign policy that prevents technology transfer from outside companies? 2. How much experience does the indigenous agricultural division have with modern technology? 3. Have you encountered any cultural obstacles to the implementation of the fruit dryer? 4. Were there any additional problems and/or opportunities with that cultural environment? 5. Do the individuals' roles, goals, behavior correlate with the system's design and goals? 6. How developed is the business and agriculture sector of the economy? 7. How does the government influence the agricultural and business sector?
C. <u>Labor Requirements</u> Considering the equipment and labor necessary is a vital step in planning for future implementations. Important factors include the required knowledge and skill level of the workers, as well as the on-site opportunities available for training them to operate the machine. If the required labor is not available to install, operate and maintain a fruit drying system, the project is highly unlikely to succeed. Likewise, technology that displaces workers is rarely accepted by the local community.	1. What is the number of workers required in the operations of the fruit dryer and their different jobs? 2. Do you have an available workforce to support that number? 3. How many hours of work per day is required of the workforce? 4. How is the labor supervised? 5. Are the workers paid; if so, how much? 6. Are there employment or labor laws in this country? If so what are they? 7. How often are the workers available to operate the dryer?

C. <u>Labor Requirements</u> (continued)	8. Do all the workers have all the necessary skills; if not, can they obtain training? a. How is this training delivered? 9. Do the laborers have a desire to work? 10. What equipment is needed to achieve the planned production level? 11. Do the workers have a way to express problems they run into with the working conditions? 12. Is the implementation of this technology going to displace workers?

D. <u>Costs</u>
 	
The costs of transportation, delivery, energy, and the dryer itself can depend largely on the country's location, and these factors can significantly affect the feasibility of an implementation. By considering the costs involved beforehand, funds can be loaned and organized in order to ensure that the project will have enough funding to be successful.
	1. How is the dryer to be paid for?
	2. If money is to be borrowed, who is it to be borrowed from?
	3. Does the loaner need to be repaid and by when?
	    o What will be the repayment and interest costs over this period?
	    o What happens if repayments are not made?
	4. What are the transport costs?
	    o How far is the field to the plant?
	    o How far is the plant to the buyer?
	    o Can transport costs be shared with other dryer producers?
	    o Are there other products which can be sold at the same time?
	    o Are there any products that can be brought back which can be sold profitably in the local village?
	5. What are the energy costs?
	    o Do these costs fluctuate?
	6. What are the material costs?
	7. What are the fruit packaging costs?
	8. What are the maintenance costs?

E. <u>Partners</u> Making connections with potential partners is an important step when working with large projects that require multiple groups or organizations to succeed. By analyzing a partner's motives and goals for the project, crucial relationships can be formed to increase the resources behind an implementation.	1. Does the partner align with the overall goals of the project? 2. What is the value this partner sees in the project/ what enticed the partner to join? 3. What will the level of involvement of this partner be in the project be? 4. How did the partner discover this project? 5. What does this partner contribute to the project?

E. <u>Partners</u> (continued)	6. Will the partner receive payment for their contributions? 7. What are the potential partner's expectation on the time involved? 8. What is the potential partner's standing in the community to be affected by this technology?
F. <u>Market Interest</u> Market interest is another important consideration when implementing a fruit dryer in a new location to ensure that the fruit will be sold after it is dried. Market interest can depend on the types of fruit that are being dried and the areas in which they are being sold. Without proper market interest, there is no purpose for implementing a dryer in the first place.	1. Does the quality of the fruit dried meet the buyer's requirements? 2. Does the fruit dryer meet the regulations and sanitation standards of the country? 3. Is there a local, regional or overseas market for the product? 4. Who and how big is it? 5. Can you handle that size? 6. Where can the dried fruit be sold? 7. How can dried fruits be packaged for sale?
G. <u>Fruit Dryer Mechanics and Operations</u> The mechanics and operations of the fruit dryer can have a major influence on the possible areas of implementation, since mechanical aspects of the dryer may demand specific requirements in order for the machine to function properly. Considerations such as the maintenance, inspection, and the energy source required can quickly eliminate certain locations if proper service and utilities are not available.	1. Who has ownership over the technology rights of this fruit dryer? 2. How does the fruit dryer operate? 3. What makes this fruit dryer better than others? 4. Are there any disadvantages? 5. What is the step-by-step process to dry the fruits? 6. Were there any obstacles in terms of mechanics or operations? 7. What is the fruit dryer made out of? 8. How long does it take for the fruits to be dried? 9. Is there room for upgrade in the current environment or a need to replace the whole system? 10. Can the fruit dryer be adapted to different fruits? 11. What is the current energy source? 12. Have you looked into new energy sources? 13. Is there a process to temporarily store fruit before being shipped? 14. Does the site have the following requirements: a) Reliable electricity b) Adequate lighting c) Quality road system 15. How is maintenance/inspection carried out on the dryer? 16. Where could spare parts for the dryer found?

G. <u>Fruit Dryer Mechanics and Operations</u> (continued)	17. Is the building big enough for your production needs? 18. How often does the fruit dryer need to be cleaned? What is the product used to clean it? 19. Is the fruit dryer protected against insects? If not, what improvements do you need to make? 20. Are the quantities, quality and safety of the water adequate for processing and cleaning? 21. Do you have hand-washing facilities?

4.2 Outcome #2: Fruit Dryer with Recent Modifications

The fruit dryer we created (Figure 12) is composed of a heat pump system, an electrical system, fruit pallet assemblies, and chambers made from laminated plywood and wooden beams. The construction process took approximately four weeks to complete while working with various technicians at NTB. This resulted in a heat pump fruit dryer that closely resembled the design specifications of previous models, but included several modifications (see Section 4.6). Some alterations were a result of outdated engineering drawings that needed to be changed in order to fill gaps between panels, while other modifications were made to improve certain aspects of the dryer over previous designs. Without going through the process of constructing the fruit dryer, creating the user manual would not have been possible. This experience allowed us to document the building procedure through photographs as we went, and also helped us to gain a much more thorough understanding of how the machine and all of its sub-systems function. Stefan Bertsch is currently uncertain of what will happen to the fruit dryer after we leave, but it is likely that the dryer will be stored at NTB until a future implementation or other purpose is found.

Figure 12. Completed fruit dryer

4.3 Outcome #3: User Manual

A user manual was created to help guide the communities in which the fruit dryer is being implemented through the process of assembling and operating the fruit dryer. The goal of the manual is to give more autonomy to these communities in order to reduce their reliance on NTB and Ökozentrum throughout the implementation process. Additional information regarding the creation of the manual was described in Section 3.3.1.

The user manual was broken down into four chapters. Chapter 1 is an overview of the three sub-assemblies of the fruit dryer (chambers and pallets, heat pump system and electrical system) and also includes a table that estimates the time necessary to complete the various portions of the fruit dryer and dry one load of fruits. Chapter 2 comprises all important safety precautions during the construction and operation processes. Chapter 3, the main chapter, describes the construction steps for each of the three sub-assemblies with CAD diagrams and photographs that were taken during the process. Finally, Chapter 4 outlines the procedures to prepare the fruits and operate the dryer once installation is complete, and shows how to turn on the heat pump, adjust temperature, load the machine, change the loads, and adjust the pallets during the heating cycle. The manual describes how to dry apples (with and without the peel) and mangoes. Different fruits and vegetables can be dried, but the preparation steps and drying time need to be adjusted accordingly.

Besides the step-by-step instructions to assemble and operate the fruit dryer, the user manual was comprised of additional relevant information. The necessary tools to build and install the dryer were described in the manual, including the tools that are critical to have and those that are helpful but not completely necessary. A priority ranking system was used to label tools as either low, medium or high importance. Additionally, some parts of the dryer do not need to have specific dimensions and can therefore vary depending on the available hardware in the implementation locations at the time. These components were noted in the user manual to allow for greater flexibility during on-site construction when hardware is scarce. The way in which the fruit dryer is constructed can be adapted based on the available resources in the community that is building it. Therefore, the manual was designed to convey the adaptability of the building strategy for the fruit dryer while highlighting important design aspects that must be met (e.g., the drying chamber must be air-tight, waterproof, and food safe).

Some captions of the user manual are shown on the next page. An online PDF of the complete user manual can be found at:

https://drive.google.com/file/d/0B51TOeblF9bHVnBHNTZDMnhfTmc/view?usp=sharing

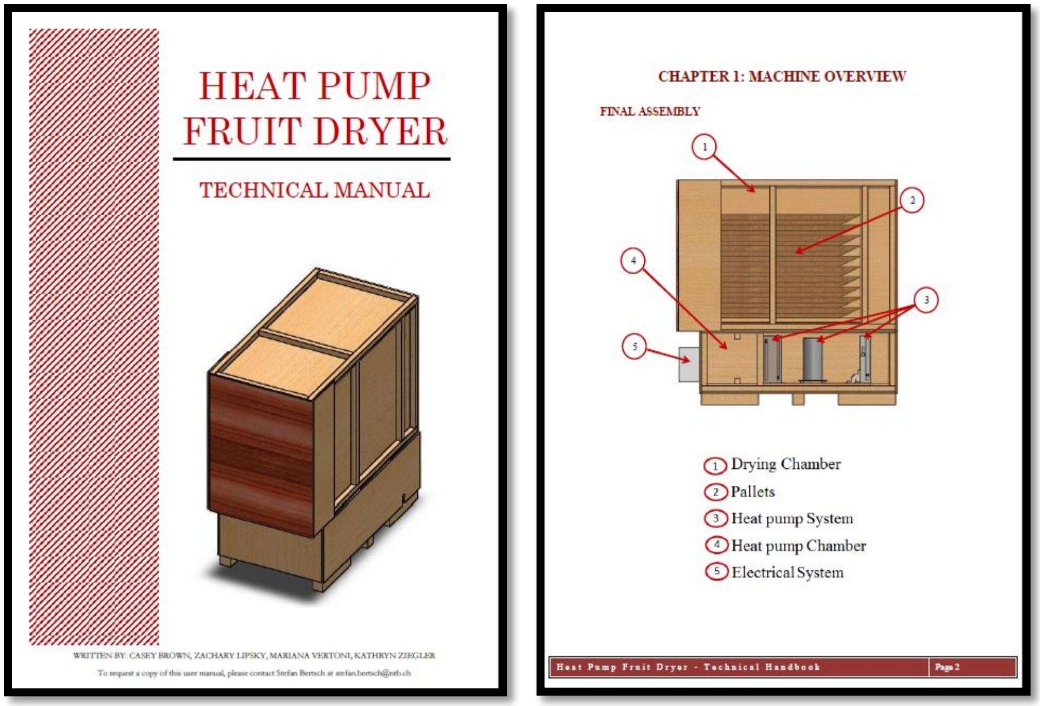

Figure 13. Title page and overview page of the manual

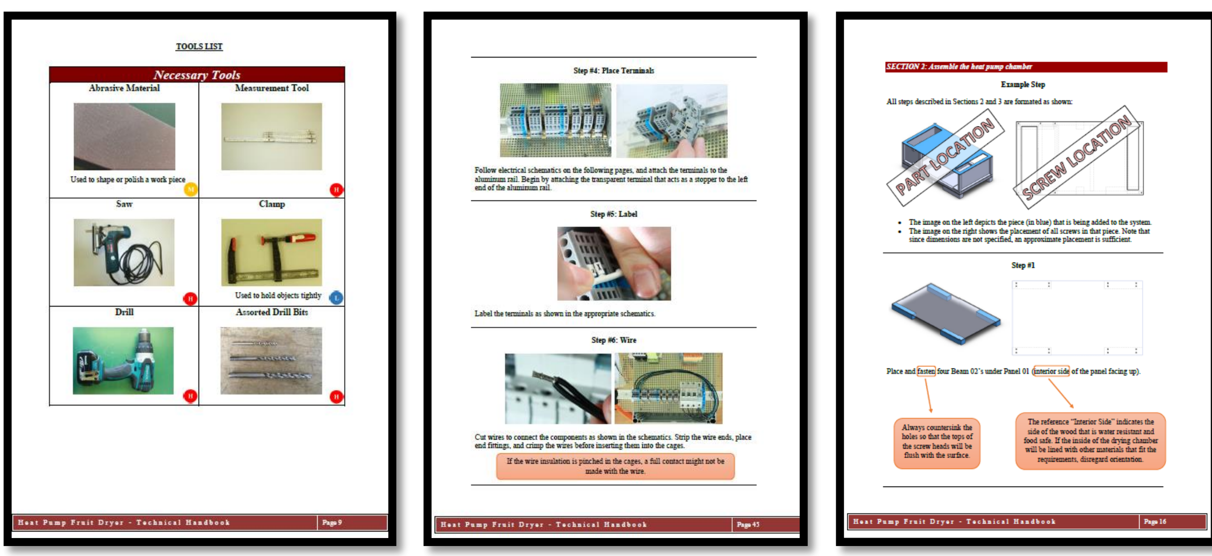

Figure 14. Excerpts from assembly sections of the manual

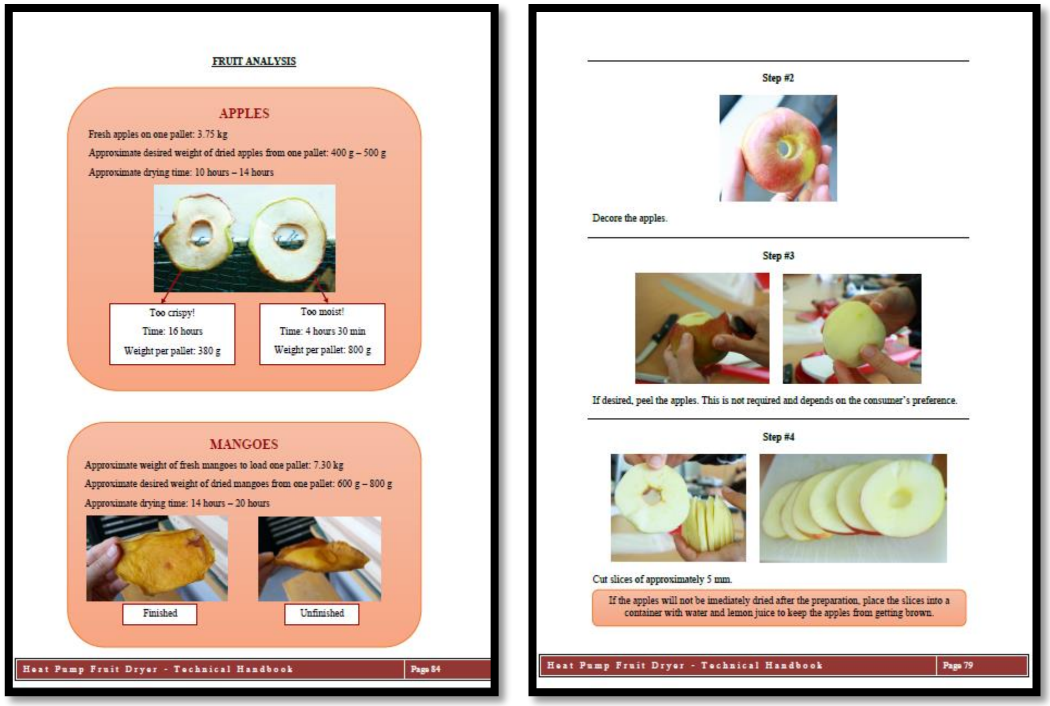

Figure 15. Excerpts from the operations section of the manual

4.4 Findings Regarding the Process of Building the Fruit Dryer

To write the user manual, we first worked with NTB to build the fruit dryer from scratch. This process was an enriching experience that allowed us to learn many of the steps and challenges involved with implementing the fruit dryer. Our findings and lessons regarding this process are listed below:

Building the fruit dryer takes more than a week.

Our first major finding was that building the dryer takes much more time than previously expected. Our initial estimate was that the dryer would take one week to build, but we ended up taking four weeks. Building the dryer would have been faster if we did not have to write the user manual simultaneously. On the other hand, we had an NTB technician helping us at all times, which sped up the process. Local communities in the new implementation locations will not dedicate time to write the manual, but ideally they will not have an NTB technician with them. Therefore, it is hard to estimate exactly the time required for these communities to build the fruit dryer themselves.

Working with technicians is a learning process.

Working with technicians at NTB was essential throughout our project, but it was a learning process. Our first difficulty was the language barrier. Most technicians at NTB speak English, but the technician who helped us on a daily basis with the entire assembly of the dryer spoke mostly German. Communication was challenging in the beginning, but he worked hard to bridge the language gap and learned a remarkable amount of English by the end of our project. In the last weeks, communication flowed smoothly and naturally. It was also hard to adjust to the pace of the technicians initially. They had their own projects to work on, so we felt uncomfortable interrupting them to get help on our project. They knew we were pressed for time and were very knowledgeable in what they were doing, so they occasionally built faster than we wished. We had to learn to interrupt them and let them know that we had to understand all steps carefully and in detail because creating a user manual was the priority for our project. Lastly, we found out that it is difficult to explain the real meaning of the Interactive Qualifying Project (IQP) requirement. Since we are engineering students coming from a polytechnic university in the United States, the logical assumption for everyone is that our focus should be on technical work rather than on social and cultural aspects. We made progress in explaining to the technicians what our goals and focuses were, and by the end of the term, they gained a better understanding of what IQP encompasses.

Working with all technicians across social and cultural differences was a pleasant learning experience that can be illustrative of the challenges that come with technology transfer. Every time people cross borders to implement technology, communication may be hindered due to language barriers and cultural assumptions. When communication is inefficient, aligning goals becomes an extra challenge. In many cases, foreign technicians and organizations arrive to developing countries to help in the implementation process, but their interaction with local communities is a learning process. Similarly to our experience, it takes time for technicians and local communities to adjust to each other's pace, align goals, and learn the best way to communicate. Thinking about these lessons, we worked to create a manual that is as user friendly as possible, having pictures speaking for themselves, so that dependence on technicians is minimized.

4.5 Findings Regarding the Process of Writing the User Manual

Similarly to building the dryer, we found out how much work and time are required to create a user manual, and how much can be learned from this experience.

Refined layouts can be highly effective while appearing to be straightforward.

Our first major finding was that document design is not as simple as we anticipated. It takes time to choose the best style (font, color, layout for tables, etc.) for the user manual to follow, one that resembles a standard manual and is also easy to read and understand. Interestingly, we found that as the design was refined, it became more and more straightforward in appearance and increasingly effective in conveying information. Since the manual will be printed (perhaps in black and white for some locations), we had to make sure all text was legible and all images were clear on paper. The sizes of the images used in the manual had to be changed throughout the process to ensure that images were clear when printed, but did not take up too much space in the manual. Finally, we struggled in the beginning to determine the appropriate ratio of text to pictures, tables, and CAD drawings.

After experimenting with many different manual layouts, we found that it is usually best to go with a simple, linear design, so that the eye can follow a path without missing any important information. We also found out that well composed photographs can greatly reduce the amount of text necessary to convey ideas and instructions. Lastly, having a combination of CAD diagrams and photographs can create a layout that remains straightforward while showing both a simple representation and a realistic image of the assembly.

It is difficult to gauge the appropriate level of detail for the manual when the knowledge of the target audience is unknown.

One of the hardest aspects of writing the manual was to make sure it was appropriate for our target audience. Understanding what could be assumed about the experience, educational level and English language abilities of the entire audience was a challenging and continuous process that required us to talk to various stakeholders. The manual was written for carpenters and electrical technicians. However, since we are not carpenters or electricians, it was difficult to measure what is considered to be common knowledge for them. For example, we could not easily determine how many of the tools and schematics needed to be explained.

By asking Stefan Bertsch and technicians at NTB what would be common knowledge to these professionals, we gained a better understanding of the level of detail in which the manual needed to be written. After writing the electrical section of the manual, for instance, we gave it to the electrical technician at NTB for him to review to make sure that no information was missing or redundant. Getting feedback from professionals in the same area of expertise as our target audience was an effective strategy; nevertheless, we are aware that the knowledge level of technicians will likely vary significantly depending on the location in which the dryer is implemented. Testing and refining the manual is likely to be the most practical way to respond to this uncertainty.

It is difficult to write a manual that applies to diverse locations worldwide.

Aside from making sure the manual was appropriate for our target audience (carpenters and electricians), we had to ensure it included enough information to be applied to all possible locations receiving the dryer. Some places will receive certain components from NTB and Ökozentrum and some will order all of them locally. To make a manual appropriate for all situations, we had to assume that no components would be shipped at all, and thus we had to catalog all of them. We also realized it is an involved process to find out what materials and tools are readily available in each location where the dryer is implemented. Christian Huber and Akos Lukacs helped us in this task, based on their experiences in Burkina Faso. Since the dryer is adaptable, we included in the manual notes about which materials/tools were necessary and which could be substituted in case they were not available at a certain location. However, once again, determining the priority level for each material required input from technicians.

4.6 Findings Regarding the Fruit Dryer Itself

In the process of building the fruit dryer and writing the manual, we had some important findings about the machine itself:

The fruit dryer is adaptable and is still in the prototype phase.

Differently from what we expected, the fruit dryer is very adaptable and is still in the prototype phase. For every new implementation, technicians at NTB and Ökozentrum modify the dryer to improve one or more of its aspects. Therefore, the design for the dryer is not yet finalized.

A significant finding about the dryer was that it can be adapted to suit the resources and materials available in the community where it is implemented. The dimensions of panels and the way they are cut and assembled, for example, have mostly been modified in the fruit dryer we built. Because of that, we had to create CAD models and drawings from scratch. Also, the drying and heat pump chambers do not necessarily need to be made of laminated wood. Any material can be used, as long as the drying chamber is guaranteed to be air tight, waterproof, and food safe (even at high temperatures). On the other hand, the evaporator, condenser, compressor, and ventilator are unique to the fruit dryer's heat pump system and must follow exact specifications before any modification occurs.

Corrugated roofing can replace aluminum as the material for the water collector.

While constructing the dryer, we found a substitution for the material used to build the water collector located underneath the evaporator. Currently, the collector is made out of aluminum, but aluminum and sheet metal in general is difficult to find in Burkina Faso. After doing some research and talking to Stefan Bertsch and a few NTB graduate students, we found out that fabricating the water collector out of corrugated roofing would be a cheap alternative that uses readily available material. Christian Huber and Akos Lukacs approved the idea and confirmed that corrugated roofing is common and available in Burkina Faso. For the fruit dryer we built, we used steel sheet metal to simulate the corrugated roofing because NTB already had this material in stock. By hammering corrugated roofing into rough sheet metal, the same process can be used to fabricate a water collector. In addition, we designed a different method of fastening the evaporator and water collector in place. The previous method used metal brackets with aluminum blocks as a mounting system. We replaced this system with wooden brackets that hold the evaporator and water collector in place to further reduce the use of aluminum in the construction process.

The fruit pallets can be stacked on top of each other to allow for removal and adjustment during the uneven drying cycle.

To address the issue of uneven heating in the drying chamber, we discussed possible new designs for the pallets with Stefan Bertsch, Akos Lukacs, and technicians at NTB. After creating a few design sketches, we decided together with Stefan Bertsch to prototype a new system (Figure 13) that could be used to allow pallets to easily be shifted during the drying cycle. As of now, the fruits on the bottom pallet are dried faster than the ones on the top pallet, so workers often need to manually change the order of the pallets. To prevent this, the fruit pallets are stacked on top of each other in the new system. The user now takes out the bottom pallet when it has finished drying, causing the other pallets to fall to a lower position. A new pallet of fruit can then be inserted on top of the stack, and this process can be repeated to increase efficiency and ensure that all fruits are dried to the same extent. This system also removes the need to open the entire door to the drying chamber to remove a single pallet. Two small doors allow access to the upper and lowermost pallets, so that one can be removed and one can be inserted without opening the large door and losing a large quantity of heat. For the dryer we built, the original door was used due to time restrictions.

Figure 16. New design for the pallets in the fruit dryer

4.7 Findings Regarding Expanding the Fruit Dryer to New Locations

After the interviews we conducted in the first two weeks, we gained a much clearer understanding of the real meaning behind the fruit dryer and the reasons for its creation.

The fruit dryer should be promoted only where communities will benefit.

When Akos Lukacs was working for Ökozentrum and contacted Stefan Bertsch at NTB to create a low-cost heat pump fruit dryer, his intention was to allow developing countries to have environmentally sustainable fruit drying technology of the same standard as in Switzerland. His main goal was to benefit the local communities in these countries by giving them an opportunity to earn extra revenue through the sales of premium dried fruits. When we interviewed Akos Lukacs (A. Lukacs, personal communication, March 19, 2015), he emphasized the importance of making sure every new implementation is aligned with the original meaning of the project. The fruit dryer is not supposed to be implemented in a location if it aims to bring profit to an organization/company. This was one of the most important findings for our entire project, which turned out to also be a recommendation for future projects related to the fruit dryer. The fruit dryer should only be expanded to new locations if the local communities are the ones to be benefited.

It can be difficult to predict whether or not a community will benefit from an implementation. Our analytical tool discusses several aspects, such as labor and culture, of local communities that can be supported or damaged depending on the organization in charge of the implementation. For example, if the fruit dryer increases the profit of the organization but displaces local workers or disrupts the farming community, the location where the dryer was implemented could easily suffer from the new technology. Therefore, the motives of the organization and the characteristics of the local community must be researched beforehand to determine whether or not they will benefit mutually from the fruit dryer. The considerations listed in our analytical tool can serve as a convenient resource to ensure that the motivations of the organization, the local community, and the creators of the project are all aligned.

It is also not straightforward to determine what constitutes a benefit to the local communities. They can benefit from the dryer financially if it brings an additional source of income or increases the revenue of the community as a whole. They can benefit from the dryer environmentally if it lowers carbon emissions, uses less energy than previous methods, or decreases the amount of waste generated. Also, communities can benefit culturally if the drying technology helps to maintain local traditions and practices. To guarantee that the communities are continuously being benefited, Akos Lukacs emphasized that for every implementation, the users of the dryer need to have a method of communicating their accomplishments and problems to NTB and Ökozentrum (A. Lukacs, personal communication, March 19, 2015).

Christoph Günner's goal of implementing the fruit dryer in Indonesia is to benefit the local communities.

When interviewing Christoph Günner (C. Günner, personal communication, March 27, 2015), we followed Akos Lukacs' suggestions and tried to emphasize the real meaning behind the fruit dryer's creation. Our goal with the interview was to understand Christoph Günner's intentions for the implementation of the fruit dryer in Bali, and then determine if it should be one of our recommendations or not.

As can be seen in our interview plan (Appendix A.4), we learned that Christoph Günner is involved with Tri Hita Karana, a foundation in Bali that works with small scale projects. Farmers in the cooperative work with permaculture projects, producing cashews, cocoa beans, moringa powder, and diverse dried fruits. Bali is too humid to use solar dryers year-round, so the cooperative traditionally uses oven dryers, which generate a great deal of smoke. Christoph Günner is looking for alternative drying methods to enhance the quality of the cooperative's dried products. In doing so, his main goal is to increase workers' revenue by selling all their dried products to the external market (United States and mainly Europe).

Christoph Günner does not foresee any reluctance from the farmers during the implementation of the heat pump dryer because the leader of the cooperative is an engineer that studied in the United Kingdom. The fruit dryer would be operated solely by the workers at the cooperative, who could easily receive training if needed. Furthermore, the tourism industry in Bali is prominent, so air conditioners are frequently installed in hotels and resorts by local technicians. Based on this fact, it should not be difficult to find electricians and materials needed to install the heat pump fruit dryer. He mentioned that problems with electricity could arise, but the cooperative has a diesel generator as a backup. On the other hand, the finances for the implementation should not be an issue. His NGO in Germany, Organic Island Foods, is trying to obtain funds from the German embassy in Indonesia, the Indonesian embassy in Germany, and other private institutions. If no funding can be obtained, Organic Island Foods is able to cover the costs of one implementation.

In the interview, Christoph relayed an interesting cultural aspect about implementing the heat pump fruit dryer in Bali. In Indonesia, he said, Islam is the most commonly followed religion. In Bali, however, the majority of the population follows Hinduism. Hindu farmers generally work less hours than farmers from other parts of the countries because they participate in many religious ceremonies. Thus, they receive a smaller revenue at the end of the month (some earn less than €1 per day). This is causing many farmers to sell their lands and move away from agriculture to work in tourism. Christoph Günner's objective is to give extra revenue for farmers in Bali through the sales of premium dried fruits, so they can maintain their culture (Hinduism) and way of life (agriculture).

Christoph Günner would like to have the first heat pump fruit dryer implemented in the cooperative by November because this is when the rainy season begins and solar dryers can no longer be used. Based on the interview, we found out that his goals are aligned with Akos Lukacs' goals and that the fruit dryer would benefit the local communities of Bali, Indonesia. Therefore, we concluded that implementing the fruit dryer in Tri Hita Karana Bali Foundation would be one of our recommendations.

Akos Lukacs is planning to lead an implementation of the fruit dryer in Ecuador in 2016.

When we interviewed Akos Lukacs (A. Lukacs, personal communication, March 19, 2015), we found out that he is planning to lead an implementation of the fruit dryer in Ecuador in 2016. Akos Lukacs visited the foundation Salinerito, which currently uses gas dryers made of stainless steel to dry and export mushrooms to Switzerland. The gas dryers used by Salinerito present the same technical and environmental problems as the ones in Burkina Faso. Furthermore, gas prices are rapidly increasing in Ecuador. Thus, Akos said, implementing the low-cost heat pump fruit dryer would certainly benefit the local communities. He plans to go to Ecuador next year for the implementation, but would like for the basic chambers to be built before he arrives. This way, he would only need to install the heat pump system. Akos affirmed that creating a user manual would be the most effective way to help him with the expansion of the dryer to Salinerito.

CHAPTER 5: Conclusion and Recommendations

After working on the project for fourteen weeks, our most meaningful conclusion was that technology transfer is a highly complicated process that requires careful consideration. We only understood the real complexity of shipping technology to another country after we started building the fruit dryer ourselves in order to create the user manual. Our goal in writing the manual was to facilitate the technology transfer process by making the local communities in developing countries independent from NTB and Ökozentrum. However, by building the dryer from scratch, we realized the process is slower and more complicated than we previously expected - even with NTB technicians helping us at all times. Thus, at least for the implementations happening in the near future, we do not believe the manual will give the local communities all the autonomy we hoped for. Based on our experience, the manual is still not complete enough to eliminate all assistance from NTB or Ökozentrum, but it does move the technology transfer process closer to this ideal. Even if NTB technicians are still required, their participation in the installation of the fruit dryer can be reduced with our user manual.

During the preparation term, we created an analytical tool encompassing questions to investigate any fruit dryer implementation. Our intention was to apply all considerations presented in the analytical tool (culture, costs, price and availability of fruits, labor requirements, market interest, fruit dryer mechanics and operations, and partners) to our project to then choose potential new locations for the fruit dryer to be implemented. Our initial idea was to recommend expansion to locations where costs would not be high, market interest would be sufficient, labor requirements would be met, cultural aspects would be respected, and fruits would be available. After talking to Akos Lukacs, however, we concluded that we misjudged the importance of the most relevant consideration: the intentions of the organization/individual leading the implementation. We underestimated the significance of understanding what it takes to cultivate this role of a leader. Before addressing any other aspects of our analytical tool, we had to ensure that the local communities would be the ones benefitting from the implementation of the fruit dryer. As explained in Section 4.7, the real meaning behind the fruit dryer's creation is to improve communities in developing countries through the use of environmentally sustainable technology, and the leaders need to be aligned with this ideal.

5.1 Recommendations

The remaining section of this chapter lists all of our major recommendations. They are related to our findings and lessons during the process of conducting interviews, building the fruit dryer, and writing the user manual. We hope that these recommendations, along with our user manual, will help NTB and Ökozentrum to continuously make the technology transfer process for their fruit dryer more efficient. Most recommendations are directed to the major stakeholders of the project, but the last recommendations are directed to WPI.

Recommendations for the Construction Process

1. Fabricate the water collector out of corrugated roofing in all locations where aluminum and sheet metal are expensive or not readily available.
2. Replace the previous mounting system for the evaporator with wooden brackets to avoid the use of thick aluminum blocks.
3. Use an improved system of mounting the pallets to help solve the issue of uneven heating in the drying chamber.

As we were building the dryer and working with the technicians at NTB, we came across several aspects of the dryer that could be improved. These ideas were successfully prototyped in this version of the dryer, and we recommend that future dryers are built with these modifications to increase their adaptability, reduce costs, and improve the efficiency of the drying operation. For a detailed explanation of these modifications, refer back to Section 4.6.

Recommendations for the Operations Phase

1. Utilize the water collected from the evaporator for cleaning, not for consumption.
2. Explore other power source options to make the dryer independent of the local electrical grid.

Once the dryer is in the operations phase, there are still ways in which it can be modified and the process can be improved. The drying process removes a significant amount of water from the fruits, which is collected from the evaporator as deionized water. This purified water can be used to clean dishes, houses, or the dryer itself. However, deionized water is not safe to drink. Deionized water removes minerals from the body if consumed, since the water itself does not contain minerals. Drinking deionized water has been shown to increase the elimination of sodium, potassium, calcium, chloride, and magnesium ions from the body and can lead to serious health effects if consumption is sustained (Kozisek, 2005).

Also, there are possible alternative energy solutions that could be explored in order to remove the dryer's dependence on the local electrical grid. This would allow the dryer to continue running when power outages occur, and would place less strain on the grid itself, especially if multiple dryers are implemented in one location. Possible power source options include using photovoltaic cells or biogenerators that use biogas produced from spoiled fruit. Photovoltaic cells are already being used in Burkina Faso as a backup power source for the dryer, while biogenerators have not yet been tested. More information can be found in sections 2.2.2 and 2.3.1.

Recommendations Regarding the Adaptability of the Fruit Dryer

1. Encourage technicians in developing countries to adapt the fruit dryer to the resources they have available, while ensuring the drying chamber is air-tight, waterproof, and food safe.
2. Encourage the local communities in developing countries to experiment with drying different fruits and vegetables.

As explained in Section 4.6, the fruit dryer is adaptable and thus can be built in different ways. Even though we emphasized throughout the user manual that many aspects of the dryer can be modified, we are aware that most people tend to follow the exact steps described in a manual rather than experimenting with other alternatives. Knowing that people can be apprehensive of the risks of an innovation (and many times avoid it), we recommend that the organization/individual leading the implementation encourages and gives all necessary support for local communities to make any modification that suits their needs. As was reiterated by Akos Lukacs and Christian Huber, when communities actively participate in the construction and modification of the fruit dryer, they gain a sense of ownership to the machine and feel included in the technology transfer process. It is crucial, however, to inform the communities about the parts of the dryer that need to meet certain requirements. For example, the dimensions and materials of the drying chamber can vary, but the chamber must be air-tight, waterproof, and food safe. Likewise, the condenser, compressor, evaporator, and ventilator are unique to the fruit dryer's heat pump system and must follow exact specifications (noted in the manual). The tools listed were ranked as low, medium or high priority to, once again, promote the use of tools available on-site whenever possible.

We also recommend that the leading organization encourages the communities to experiment with drying different fruits and vegetables. The choice of the fruit or vegetable will depend on the market interest for that location. The size and thickness of the cut slices can also vary, depending on the consumer preferences. Each location should make decisions based on what dried products will bring them more sales - and consequently more revenue. It should be noted, however, that the preparation steps and the drying time will differ based on the choices made.

Recommendations for the User Manual

1. Revise the user manual because this is not the final version.
2. Keep updating the user manual after every implementation to incorporate the modifications made.

The fruit dryer is still in the prototype phase, and is constantly being adapted and modified. This is a process that will continue in the future, so the user manual will need to be revised to reflect design changes and updates accordingly. Therefore, this version of the manual is by no means the final version. This manual is our best representation of the fruit dryer that we built, and it will continue to evolve with time to suit future implementation sites and future dryers. Since the fruit dryer is highly adaptable, it is unlikely that dryers in different locations will look the same. As described in the previous recommendation, the construction process can vary depending on the materials and tools available on-site, and the design of the chambers can be adapted to suit the local climate and the fruits that are being dried. Ideally, the manual should include different ways in which the fruit dryer can be built, with examples from different locations. A "frequently asked questions" section of the manual to address problems that can arise during either the construction process or the operations phase would also be helpful, as well as a page with contact information to professionals at NTB or Ökozentrum to troubleshoot additional problems. Lastly, a section that outlines cleaning and maintenance instructions for the dryer could serve to increase its lifespan and ensure that the locals are taking care of the machine and not simply running the dryer until it breaks.

If an implementation is being considered in a new location, the user manual could be sent to the organization in charge of the implementation to give them a better idea of what is required to build and operate the fruit dryer. There are many questions involved with transferring the fruit dryer to new locations, so an implementation guide could be a convenient final chapter in the user manual. This guide would be based on our analytical tool, and would provide useful considerations to assess a possible new location for the fruit dryer and check if the motivations of the organization and the local community match. The guide could also act as an alert to the social context in technology transfer processes by raising important cultural questions before a new implementation begins. The questions are meant to ensure that the local communities will accept and benefit from the dryer, that their culture and beliefs will be respected, and that the technology is suited to their abilities and not overly complex.

Recommendations for Current and Future Implementations

1. When expanding the fruit dryer to new locations, make sure that the dryer aims to benefit local communities and not to profit the organization implementing it.
2. When expanding the fruit dryer to new locations, ensure that workers on-site have a way of communicating with NTB and Ökozentrum about their problems.
3. For current and future implementations, create a monitoring system to constantly oversee the operation of the fruit dryer, the workers' dynamics, and the recycling of materials.

As emphasized in Section 4.7, before the fruit dryer is sent to a new location, the motives of the organization in charge must be thoroughly considered. The low cost fruit dryer was created to benefit local communities, not individual organizations, so the goals of both groups of people must be aligned in order for an implementation to occur. It is important to discuss the motives behind those who are interested in the fruit dryer and make sure that the dryer does not simply become a profitable business for the organization implementing it.

Another important aspect of implementing the dryer is making sure that the locals who are operating the dryer have a method of communicating problems to NTB and Ökozentrum. This support system is extremely important because when problems arise, the dryer is at risk of being sold for parts or recycled for another form of use if technicians or professionals cannot be contacted to come help. Also, the working conditions of the locals should be the concern of both the organization in charge and those who first implemented the dryer. Having a group of individuals who are not on-site and can help with social and cultural problems is valuable if the organization in charge becomes unresponsive to the needs of the workers. Following Akos Lukacs' suggestion, we recommend the creation of a "monitoring system" that could allow NTB and Ökozentrum to remain in contact with local communities after implementations take place to ensure that the operation runs smoothly and issues become resolved. This system would ensure that the fruit dryer is being maintained, the workers are content, and materials are being recycled properly. Our analytical tool could serve as a convenient resource for creating this system, since it provides concrete ideas of aspects to be considered during both the project planning phase and the 'monitoring and support' phase. Creating a close network with current and future implementation sites is crucial in order to prevent long-term problems and maintain an operation that is aligned with the motives behind the fruit dryer.

Recommendations Regarding the Implementations in Indonesia and Ecuador

1. Proceed with the implementation of the fruit dryer in Indonesia with Christoph Günner.
2. Utilize the user manual to facilitate the implementation of the fruit dryer in Ecuador in 2016.

Section 4.7 explained in detail Christoph Günner's intentions for implementing the low-cost heat pump fruit dryer in Bali, Indonesia. According to Christoph, the dryer would be implemented in the Tri Hita Karana Bali Foundation and would benefit farmers by giving them extra revenue through the sales of premium dried fruits. With a higher income, said Christoph, the farmers would be able to maintain their culture (Hinduism) and way of life (agriculture). We were pleased with Christoph Günner's goals for the cooperative in Bali, and therefore we recommend the expansion of the fruit dryer to Indonesia. Since the import taxes in Indonesia are extremely high, we also suggest that the user manual is utilized in this implementation to allow the community to receive as few components from NTB and Ökozentrum as possible and reduce costs significantly.

On a similar note, the user manual could be sent to Ecuador to facilitate the implementation of the fruit dryer in the Salinerito Foundation in 2016. As described in Section 4.7, Akos Lukacs will lead this implementation, but would like for the chambers to be built before he arrives. Allowing the local communities to assemble the chambers by relying only on the instructions presented in the manual, without any outside help, would be a valuable opportunity to measure how comprehensive our manual currently is.

Recommendations for WPI

1. Research the possibility of other IQP groups continuing the project, since there are many improvements yet to be made.
2. Research the possibility of an MQP group working on the technical aspects of improving the fruit dryer.

As discussed in the previous recommendations, there are many ways in which this project could be improved or expanded. Because of this, we suggest that future IQP groups become involved with the project to address the various aspects that could continue to be improved. As mentioned earlier, Akos Lukacs discussed the possibility of an IQP to develop a "monitoring system" for previous and future implementations of the dryer that would ensure that the drying operations are not forgotten after the initial implementation, and that support is available if problems arise. Another possible IQP could be related to the cultural considerations in technology transfer processes. The project would emphasize experiences of technical and cultural exchange, explore further the notion of local benefit and leadership, and investigate the relationship among organizations leading the implementation and the communities affected by the technology. In conclusion, the project would contribute to identify what it means to combine technological know-how with culturally sensitive and well-informed local knowledge.

In addition, MQPs could be set up with NTB to focus on the technical aspects of the fruit dryer and work to improve the system from an engineering standpoint. Mechanical or Electrical and Computer Engineering (ECE) MQPs could explore methods of improving the efficiency of the dryer, experiment with different building materials, or work with alternative energy sources for powering the dryer. Also, looking into methods of re-ionizing the water collected from the evaporator could potentially be an MQP for Chemical Engineering students.

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APPENDIX A: Interview Plans for Partners

APPENDIX A.1: Interview Plan for Stefan Bertsch

Where, when, with whom, and how the interview was conducted

- Where: WPI and NTB
- When: January-March
- Whom: Stefan Bertsch
- How: Skype, email, and face-to-face

Which team members were responsible for various tasks

- Note-taking: Kathryn & Zachary
- Introducing the team: Casey
- Lead questioner: Mariana
- Writing the summary: All
- Reviewing the summary: All

Information collected

General questions, fruit dryer mechanics and operations, price and availability of fruits, social and cultural considerations, market interest, areas of improvement, and future expansions.

Interview Schedule (Questions order)

NTB (Stefan Bertsch)	
Question	Answer
General Questions	
1. What led to your involvement in this project originally? Why did you start it?	Five years ago, Stefan Bertsch and Akos Lukacs began working on a fruit dryer for developing countries, specifically Burkina Faso because of the country's heavy reliance on agriculture and connections NTB and Ökozentrum had established there. Stefan Bertsch also has an educational background in fields that are related to heat pump drying systems, such as refrigeration and thermodynamics.
2. What is NTB's mission for this project?	NTB's mission is to help individuals in developing countries earn money using environmentally friendly and sustainable technology. The technology should help to establish new jobs and improve infrastructure. These aspects can lead to improved health and fairness. The project should be self-sustainable

	in the long run. For this reason several long term collaborations are involved in this project.
3. What kind of organization is NTB (public/private, profit/non-profit, etc.) and how is it funded?	NTB is a public university. Teaching is funded by the Swiss government and state; research is funded either directly from companies, or from competitive government grants.
4. How is NTB structured, i.e., what are the main divisions of labor and authority within the NTB? What offices within the university are especially relevant to this project?	There are 7 institutes, which are involved in teaching and research. Farther up is the administration, including rector, finance department, and personal management. Above that, there is an advisory board. Parallel to the institutes, are the infrastructure and the building services. The WPI team will be involved almost exclusively with the Institute for Energy System (IES). There are additional relevant offices in which different types of heat pumps and electrical components are tested.
5. Do you have any recommendations for people to interview or resources you have available?	Akos Lukacs is a great resource on this project. He worked at Ökozentrum for the past years and participated in both implementations. Akos is also trying to expand the project to other countries. Besides Akos, there are Christian Huber from NTB, David Heubi from Gebana Afrique, and Mandu dos Santos.
Fruit Dryer Mechanics and Operations	
6. What is the fruit dryer made out of?	The fruit dryer is made primarily out of wood with metal heat pump components and an aluminum water collector.
7. Why a heat pump dryer?	High humidity during the harvest season caused fruit that was dried using traditional solar methods to spoil. Therefore, there was a need for a fruit dryer that worked year round, while also being energy efficient.
8. How does the fruit dryer work?	The dryer works using a heat pump drying system that is similar to a clothes dryer or air conditioner. It is used non-stop throughout harvest seasons, and then cleaned and re-run the following year. It was designed to be: - Robust to withstand power outages, flooding, and difficult working environments. - Sealed to prevent moisture from entering and spoiling the fruits/reducing energy efficiency. - Easily built on site. - Not used for other purposes.

9. Have the dryers been working as planned, or have there been problems with them after they were implemented?	They dryers have been working effectively, but Burkina Faso experiences frequent power outages (up to 10 a day).
10. What is the problem with the mosquito netting?	The mosquito netting sags under the weight of the fruit which causes the pallets to hit when inserting or removing the fruit. The netting also has very small holes that restrict airflow through the drying racks.
11. What is the current energy source?	Electricity.
12. Have you looked into new energy sources?	Possibilities for a more sustainable system include a combination of photovoltaic cells and biogas that is produced by rotting fruit. Biogas could be produced from the waste of mangoes or cashews.
13. How often does the fruit dryer need to be cleaned? What is the product used to clean it?	After every load, the dryer is opened and can be easily cleaned. Most parts are wiped with wet cloth, and the mosquito nettings are washed.
14. What is done with the water that is collected from the evaporator?	Right now, water is discarded. NTB and Ökozentrum are thinking of treating the deionized water (by adding salt) and use it with infants.
Price and Availability of Fruits	
15. Why were mangoes chosen as the fruit to be dried?	Burkina Faso's agricultural production is 80 percent mangoes, however they could not export them in the past because it was not economically feasible.
Social and Cultural Considerations	
16. What is the feedback from individuals in Costa Rica and Burkina Faso with implementation of technology?	BURKINA FASO: - Residents are proud, and did not readily approve of technology that would not be used in other regions of the world. They initially questioned the fact that the fruit dryer was not implemented in developed countries. - People also refused to dig into the ground more than a few feet due to religious reasons. - Lastly, residents wanted as little automation in the machine as possible. COSTA RICA: - Residents readily accepted the dryer.
Market Interest	
17. Why were Costa Rica and Burkina Faso chosen as locations?	NTB had connections in these locations. Additionally, air conditioning is common in Costa Rica and Burkina Faso, so servicing a heat pump would not be uncommon to the residents in these countries. Peru is possibly another location to implement the dryer.

18. How long ago were the dryers sent to these locations?	In Burkina Faso, the dryer was implemented in 2010, and there are currently two units implemented. In Costa Rica, one dryer was implemented in 2014.
19. Who are your competitors and how do you compare to them?	Commercial fruit dryers are available, however they are not as suitable for use in developing countries. Commercial dryers are much more expensive and complex, with long start-up times (1 hour) that severely limit productivity in areas with frequent power outages.
20. Is there a possibility for this technology to reach new markets?	Yes, there are several possible new markets in Indonesia, Ecuador, and Peru. There is a man from Germany named Christoph Günner who is trying to establish better fruit dryers in Indonesia and showed interest in our concept.
21. Has there been an attempt of implementation the fruit dryer in developed countries?	The low cost fruit dryer most likely cannot be implemented in developed countries because it is made out of wood, which does not meet most sanitation regulations within these countries.
Future Expansions/Areas of Improvement	
22. What are some specific areas of improvement you would recommend us to work on?	- Mosquito netting restricts airflow while netting with larger holes sags and leaves marks in the fruit. - The technology know-how was still not transferred to Burkina Faso and Costa Rica. - The energy supply is not reliable. - The water drip collector and components such as metal corners and distance holders are made from aluminum and other metals, which are not easily found in Burkina Faso. - Surfaces need to be protected against termites and humidity. - Drying racks could ideally be stacked and loaded all in one step. - Create an implementation guide. - Create a user manual for the fruit dryer. - Create a support website.

APPENDIX A.2: Interview Plan for Christian Huber

Where, when, with whom, and how the interview was conducted

- Where: ETH
- When: March 17th at 9:00 am (CET)
- Whom: Christian Huber
- How: Introductions, inquiry, and closing (face-to-face interview)

Which team members were responsible for various tasks

- Note-taking: Zachary
- Introducing the team: Mariana
- Questioners:
    - General questions: Mariana
    - Fruit dryer mechanics and operations: Casey
    - Social and cultural consideration: Kathryn
    - Labor requirements: Mariana
    - Future expansion/Areas of improvement: Casey
    - Closing: Kathryn
- Writing the summary: All
- Reviewing the summary: All

The information you seek to collect

General questions, price and availability of fruits, fruit dryer mechanics and operations, labor requirements, cost, social and cultural considerations, areas of improvement, and future expansions.

Interview Schedule (Questions order)

INTRODUCTIONS

- Introduce each group member
- Thank Mr. Huber for his time
- Explain the project:
    - Our goal for this project is to broaden the impact of the low-cost heat fruit dryer by either improving the already existing fruit dryer or expanding it to new locations. We researched the background to better understand how the fruit dryer works and are now trying to understand completely the impact/effect it has had in order to further improve it.

Ökozentrum (Christian Huber)	
Question	Answer
General Questions	
1. How did you start working with NTB?	Christian Huber joined Ökozentrum two years ago, and the project had already been started by Akos. Their goal was to improve the method of fruit drying in developing countries. Initially in Burkina Faso, they wanted it to be a solar dryer consisting of a tunnel of plastic that heats up from the sun and dries the fruit inside. Unfortunately, the plastic cover for the solar dryer would deteriorate after about a year of exposure to the sun. Also mango harvesting occurs during the rainy season, which limits the effectiveness of a solar dryer when it is not sunny. Because of these issues, they looked for a company that could design a dryer specifically for Burkina Faso. NTB was the partner they found to complete such a task with their heat pump drying system.
2. Other than NTB, what are your partners in this project?	Ökozentrums work closely with Gebana Afrique for the Burkina Faso implementations. Isomet is a partner for the technical aspects and equipment.
3. What is your current involvement in the fruit dryer project?	Ökozentrum is hoping to increase technology transfer and create business models for Burkina Faso through a business and technical handbook.
4. In general, were there any problems throughout the entire course of implementation in Burkina Faso?	In Burkina Faso, the locals wanted the same technology used in Switzerland or European countries in general. After the initial solar dryer failed, they found the answer in heat pump drying which is exactly the same system used in Europe. That quickly quelled any discomfort from the Burkina Faso people. In addition, air flow distribution through the fruit dryer needed to be changed once set up in Burkina Faso because the heat exchanger would ice up in the very wet climate, preventing the heat pump from operating. The best air circulation flow tested by Akos was from the bottom of the dryer up.
Price and Availability of Fruits	
5. What types of spoilage can affect the fruit from being processed in Burkina Faso?	Fungus can grow on wet fruit left overnight. For example, if there is a power outage that lasts more than two hours (which is common) and

	the fruit is still in the process of being dried, it will retain moisture and then spoil.
6. When is the rainy season in Burkina Faso?	It is during the summer time: May, June, and July.
Fruit Dryer Mechanics and Operations	
7. How long does it take for the mangoes to be dried?	The mangoes take 20 hours to dry.
8. How many dried mangos are produced per load?	110 kg of fresh mangos can produce 18 kg of dried fruit.
9. What is the currently used method of drying in Burkina Faso?	Gas drying is quite popular in Burkina Faso, but the energy efficiency is quite bad and the system is often too hot, so burned mangos are fairly common.
10. Can the fruit dryer be adapted to different fruits?	Yes, other fruits were tried, including chili peppers, kiwis, papaya, tomatoes, and bananas. Factors that are affected by using different fruits are drying time, distribution of fruits on the pallet and cutting method.
11. What is the current energy source?	Electricity is the current power source and photovoltaics cells are used as back up.
12. Have you looked into new energy sources?	Photovoltaic cells were tried as an independent energy source, but were found to be too expensive with a long wait for return on investment. Ökozentrum is also looking into a diesel back-up power supply.
13. Could spare parts be readily available for the dryer in Burkina Faso?	It depends on what spare parts are necessary. The exterior would be more easily replaced because it is simply wooden panels, however the heat compressor would be extremely difficult to replace because it is made specifically for this fruit dryer. An AC unit, though having a similar heat pump system as the fruit dryer, would not be usable for spare parts because it would not perform sufficiently for the fruit dryer.
14. How is temperature controlled for the fruit dryer?	Fruit drying is broken up into two temperature modes. The first mode gradually increases temperature to optimal drying. Then in mode two, it oscillates between two limits to save energy and money while still achieving the same quality.
15. After implementation in Burkina Faso, were there any obstacles with the fruit dryer mechanics or operations?	During the off season, when the fruit dryer is not in operation, termites eat the wooden dryer structure because the wood is no longer too hot to inhabit. To avoid this, it is preferable to continue drying fruits that are available during as much of the year as possible.

16. Would you benefit from an installation manual? The manual will consist of the construction process and a startup guide. In addition to that, what else would you like to see in such a manual?	1. Some parts are more critical than others. Consider avoiding unnecessary drawings. 2. Make sure to include a lot of pictures. 3. Fix clarity issues. 4. Document parts. 5. Clarify how to cut each part. 6. Indicate what is important what is not (prioritize) -Which tools are absolutely necessary
17. Would creating a website/forum be helpful in answering technical questions, repair parts if necessary and links to where to find sources and materials? What would be most beneficial?	Include a way to calculate the amount of power necessary to run the system.
Social and Cultural Considerations	
18. Was there a foreign policy in Burkina Faso that made it difficult to transfer technology for outside companies?	There was no foreign policies that got in the way of technology transfer.
19. How much experience did the local community in Burkina Faso have with modern technology?	They do not have much technology, however there are certain individuals that do understand how to operate them once received. Once, a fruit dryer was shipped to Burkina Faso and the compressor was not fastened correctly, coming loose during transport because of its weight. Due to technicians in Burkina Faso's basic understanding of how heat pump systems work, they were able to fix it.
20. How do most people earn a living in Burkina Faso?	Burkina Faso is a more agriculturally dependent country that is prominently subsistence farming.
21. How does the government influence the agricultural and business sector in Burkina Faso?	The government in the country has not had a huge influence as far as Christian has seen on the implementation.
22. How did farmers and the local communities in Burkina Faso react the fruit dryer?	The local communities were extremely interested in learning about the fruit drying technology.
Labor Requirements	
23. What is the number of workers required in the operations?	The number of people necessary for the operation of one fruit dryer ranges between 5-6.
24. How many hours of work per day is required of the workforce?	Women work for 5-6 hours in the morning preparing the fruit that is going to be dried. Men then operate the dryer, moving the plates within the dryer every hour to make sure they are equally dried. The drying duration of the fruit can range depending on the fruit and how it is cut. Mangos take about 20 hours to dry.

25. How is the labor supervised in Burkina Faso?	Gebana Afrique supervises Burkina Faso implementations, dealing with the workers and land property. They also repackage the dried fruit and a perform quality checks before selling it to developed countries to make sure that all health regulations are met. Gebana Afrique was given the first dryer by NTB and bought the second one.
26. Are the workers paid in Burkina Faso?	Yes, for both locations the workers are paid. Christian Huber did not know how much the workers were paid, however some of the women drove motorcycles to work, which means they have to be paid well enough to have motorcycles.
27. Do all the workers have all the necessary skills? If not, can they obtain training?	All technicians must have previous experience in the field and know about the system. These are not too difficult to come by because there are many air conditioning systems that are similar to the heat pump dryer in the country. Normal workers do not need education because they are performing more basic jobs that do not require extensive knowledge.
28. How is this training performed?	An NTB technician, Gerhard, and Ökozentrum provide the training for local technicians in Burkina Faso.
29. After implementation were there any obstacles with the labor force?	In Burkina Faso, when it rains all of the dirt roads become flooded, making travel difficult. When it rained, the workers would not show up for work. During the rainy season it rains every second or third day, which prompted the manager of the fruit dryers to buy rain jackets for all of the workers. After this, the workers began coming to work when it rained.
Cost	
30. How much does a fruit dryer cost?	A gas dryer costs €2,000 and a heat pump dryer costs €3,000-€3,500. The heat pump dryer is more expensive, however within one producing season it pays for itself. Financially, the heat pump dryer is more beneficial in the long term, but having that initial amount of money at once is not always feasible. These are the prices of the fruits dryers that are purchased and assembled in the area of implementation. If they are purchased already assembled and then shipped, they would cost almost double of the price.
31. How is the fruit dryer financed in Burkina Faso and who owns the rights?	Gebana Afrique owns the rights to both fruit dryers in Burknia Faso. NTB and Ökozentrum

	gave Gebana the first dryer and Gebana paid for 2nd dryer. Switzerland federal government, through the Swiss Agency for Development and Cooperation (SDC), funds the fruit drying project along with local privately owned Swiss businesses.
Future Expansions/Areas of Improvement	
32. Is there a possibility for this technology to reach new markets?	There are many other possible locations where a dryer could be implemented in the future including Ghana, Togo, Senegal, Chile, Indonesia, Madagascar, India, Latin America, and Tanzania. This is dependent on the different organizations interested in working with NTB and Ökozentrum.
33. Do you have any recommendations on specific areas to improve the fruit dryer?	- The fruit dryer could be improved by replacing wood with another material similar to stainless steel (which is used for fruit dryers in Switzerland) that will still prevent sanitation issues. Stainless steel is too expensive and difficult to obtain in Burkina Faso. One possible method could be plating the chamber with plastic foil that is suitable for food production. - Upscaling the fruit dryer is also a possibility.
Closing	
34. Is there anyone else you think that would be beneficial to talk to further?	- Racine is a specialist in refrigeration and worked with the project. He only speaks French, which would make it difficult to conduct an interview with him. - William Ilboudo runs Isomet in Burkina Faso which involves solar drying with photovoltaic cells that are connected to a heat pump. He is a partner for the technical aspects of the project.
35. Have you gotten into contact with David Heubi?	Christian recieved no response from David Heubi as of yet, but will try to contact him again and get back to us if he successfully gets in contact.

APPENDIX A.3: Interview Plan for Akos Lukacs

Where, when, with whom, and how the interview was conducted

- Where: Basel SBB station
- When: March 18th at 10:00 am (CET)
- Whom: Akos Lukacs
- How: Introductions, inquiry, and closing (face-to-face interview)

Which team members were responsible for various tasks

- Note-taking: Zachary
- Introducing the team: Mariana
- Questions:
    - General questions: Mariana
    - Fruit dryer mechanics and operations: Casey
    - Price and Availability of Fruit: Casey
    - Social and cultural consideration: Kathryn
    - Labor requirements: Mariana
    - Market Interest: Mariana
    - Future expansion/Areas of improvement: Casey
    - Closing: Kathryn
    - Writing the summary: All
    - Reviewing the summary: All

Information Collected

General questions, fruit dryer mechanics and operations, price and availability of fruits, social and cultural considerations, labor requirements, market interest, areas of improvement, and future expansions.

Interview Schedule (Questions order)

INTRODUCTIONS

- Introduce each group member
- Thank Akos Lukacs for his time

Akos Lukacs	
Question	Answer
General Questions	
1. What led to your involvement in this project originally? Why did you start it?	Ökozentrum started working with Gebana Afrique on a project to create a solar powered sun dryer for mangos. Akos wanted to be involved with transferring the technology know-how to the locals in Burkina. He thought that the general idea for creating a dryer using PVs was good but not well thought out. Ökozentrum and NTB had limited knowledge regarding the rainy season in Burkina Faso and the cultural aspects of technology transfer, which caused the implementation of the solar dryer to be largely unsuccessful. One of the local workers told Akos that they wanted the same fruit dryer as Europe. Akos returned to Ökozentrum and the funding contract for the solar dryer was over. Akos thought of sending a heat pump dryer to Africa, but was told by many people that the idea wouldn't work. He met Stefan for another project regarding heat pumps, and Stefan said it might be possible. Akos then went to foundations to look for funding, eventually finding enough funding to begin the low cost heat pump fruit dryer project.
2. What is Ökozentrum?	Ökozentrum is essentially just a workspace. This allows people to work on independent projects while being their own boss. Funding for projects comes from outside organizations, which need to be found independently by Ökozentrum employees.
3. What made you decide to implement the dryer in Burkina Faso?	Ökozentrum had already established contacts in Burkina Faso from the solar dryer project, and the location was suitable due to the surplus of mangos available.
4. What made you decide to implement the dryer in Costa Rica?	Akos was discovered by a Swiss farmer named Bruno who worked in Costa Rica on organic agriculture, biodiversity, fair trade, and assistance to local farmers in Costa Rica. This led to the installation of the same version of heat pump dryer that was implemented in Burkina Faso with slight modifications to the temperature control electronics.

5. What do you think are the most important points when transferring technology from one country to another?	Communication with the locals in developing countries is crucial to ensure that the technology being implemented is beneficial and no assumptions are made as to what their needs or desires are. Akos said that the most important point is making sure that the fruit drying process is independent, and does not require aid from outside organizations.
6. Who funds the fruit dryer in Costa Rica?	The heat pump dryer itself was paid for by Ökozentrum, and Bruno pays for the rest of the expenses from the operation in Costa Rica.
7. After the fruit dryer is implemented, who owns it?	In Costa Rica, Ökozentrum currently owns the dryer. However, Bruno can send the dryer back to Ökozentrum if the operation is undesirable. If the operation is desirable, then he has the option of buying the dryer from Ökozentrum. Alternatively, if Bruno sends reports detailing the beneficial results of the dryer operation, he will not have to pay for the dryer since it will create positive publicity for Ökozentrum.
Fruit Dryer Mechanics and Operations	
8. Are there any differences between the dryer in Burkina Faso and the dryer in Costa Rica?	The dryer in Costa Rica was slightly modified with additional electric temperature controllers that control what temperature the dryer heats up to. Cocoa does not need as much time to dry because there is much less moisture in the beans than in mangoes. Also, on the dryer in Costa Rica the temperature modes switch automatically, while in Burkina Faso they need to be manually changed.
9. Is there room for upgrade in the current environment or a need to replace the whole system?	- The fruits on the lower pallets are drying faster than the fruits on the upper pallets, so a method of changing the rack position during the drying process (either manually or automatically) is desired. Akos designed a prototype in which the bottom pallet can be removed when it is fully dried and a pallet of fresh fruit can be inserted on top, moving the rest of the pallets down one position. By only removing one pallet at a time, the door of the chamber does not need to be fully opened so not as much heat is lost during the removal process and exposure to the external environment is limited. - Also, upscaling the system by changing the fruit from one heat pump dryer to another or

	building multiple chambers would be more efficient, and could be good experiments. - Furthermore, a more sustainable energy source such as biogas or photovoltaics is also desirable.
10. Can the fruit dryer be adapted to different fruits?	Yes. In Costa Rica for example, cocoa is dried. Drying times vary depending on the fruit being dried.
11. Could spare parts be readily available for the dryer?	Yes. Spare parts are much more available in Costa Rica.
12. How much dried cocoa/fruit can be produced per day?	Akos is not entirely sure, but it takes about 8-10 hours to dry cocoa compared to 5-7 days using the traditional sun drying method.
Price and Availability of Fruits	
13. What fruits are available most of the year in Costa Rica? When is that?	Akos will send us information from Bruno.
14. What types of spoilage can affect the fruit from being processed?	A disease spread by mushrooms has attacked the cocoa plantations in the past, leaving them in bad condition.
15. How far away are the sources of fruit from the dryer in Burkina Faso/Costa Rica?	The sources of fruit and cocoa are very close to the drying operations in both locations.
Social and Cultural Considerations	
16. Since you participated in the implementation in Costa Rica, can you tell us more about their culture and how they received the technology?	Costa Rica is much more developed than Burkina Faso, and Akos had minimal issues during the implementation process. However, locals in Costa Rica are much more likely to take advantage of short-term profit opportunities rather than long-term investments. This can be frustrating since the short-term opportunities often lead to damaged crops and bad scenarios in the future.
17. After the implementation, were there any obstacles to the fruit dryer mechanics and operations in Costa Rica?	There were no further issues to speak of in Costa Rica.
18. Similarly as above, how did Burkina Faso react to this technology and how was your experience there in general?	In Burkina Faso, cellars to store the mangos could not be dug due to religious reasons, since the ground is where the dead are buried. The locals in Burkina Faso are also much more likely to take advantage of short-term profit opportunities rather than long-term investments. However, the fruit dryer was quickly accepted since the locals are eager to learn about new technology and gas dryer operations are common in the area.

19. Were there any additional problems and/or opportunities with both environments?	In Costa Rica, the problem is that most of the farmers don't have enough resources to restore the old abandoned creole cocoa plantations that have great potential.
20. Was there a foreign policy in Costa Rica that made it difficult to transfer technology for outside companies?	Not to speak of, in Costa Rica a local freight company was used to import the fruit dryer so there was no foreign policy intervention.
21. How much experience does the local community in Burkina Faso/Costa Rica have with modern technology?	Local communities in Burkina Faso can be more likely to continue using traditional methods even after technology is implemented, whereas local communities in Costa Rica are more similar to the United States and have a fair amount of experience with modern technology.
Labor Requirements	
22. After the implementation, did you run into any challenges with the labor force in Costa Rica?	There were no challenges to speak of with the labor force in Costa Rica.
23. How is the labor supervised in Burkina Faso and Costa Rica?	All workers are supervised by Bruno.
24. For both locations, are the workers paid?	In both locations, workers are paid a salary.
25. Do all the workers have all the necessary skills? If not, can they obtain training? How is the training performed?	Workers are trained by Akos in Costa Rica. Most of the training is regarding the temperature gauge and how to operate the fruit dryer.
26. How many workers are required to operate the dryer?	The dryer takes two men to operate and three women to wash the cocoa.
27. Do the workers have a way to communicate problems they run into with the working conditions?	If there is a problem, the workers communicate with Bruno and if necessary, he will call Akos.
Market Interest	
28. How is the dried cocoa and fruit packaged for sale in Costa Rica?	Bruno is currently drying the cocoa the make chocolate, which he is selling in plastic bags unofficially to local schools.
29. What is the local interest in Costa Rica/Burkina Faso in dried fruits?	In Costa Rica, the market for dried fruit is growing internally, whereas Burkina Faso has a more external global market since mangos are locally available and often do not need to be preserved.
30. Is there a possibility for this technology to reach new markets? Are you thinking of further expansions?	After visiting Costa Rica, Akos Lukacs visited Ecuador. They are very interested in the technology of the dryer because they are already drying mushrooms and fruits with some gas dryers (same technical and energy problems). Planning an implementation in Ecuador will be Akos' future focus.
Future Expansions/Areas of Improvement	

31. What is the current status of the implementation in Ecuador? What can we do to help?	- Salinerito in Ecuador currently uses gas dryers made of stainless steel to dry and export mushrooms to Switzerland. Akos was in Ecuador and knows that gas prices are rapidly increasing there. He is hoping to go to Ecuador next year to try to implement a heat pump dryer, and is currently thinking about the best way to get the dryer there. He pitched the idea of giving the workers the plans to build the basic chamber of the dryer before he would arrive, after which he would install the heat pump when he gets there. We could look into some transport logistic organizations and think about backup plans if the dryer does not work out as planned after it is implemented. Also, possibly look into lawyers for creating a loose contract regarding what would happen with the dryer if Ecuador chooses not to keep their first dryer.
Have there been any other countries considered besides Burkina Faso and Costa Rica? If so, who and why? What is the current standing in implementation in these countries? a. If any didn't work, why? b. If continuing, what is the status of implementation?	Vietnam is a possibility, since they have an ample work force that is motivated and a diverse range of fruits.
Stephan brought up the possibility of using this technology in Indonesia through an interested contact. (What are your thoughts?)	If the man interested in the dryer can be interviewed to gain a better understanding of his intentions, it would be more comforting for Akos. Making sure that the humanitarian goal of the dryer is addressed is Akos's main priority. He suggested the following questions: - Figure out who is benefiting from this? - Why is he doing this?
Would you benefit from a user manual? The manual will consist of the construction process and a startup guide. In addition to that, what else would you like to see in such a manual?	- Propose that the local community builds the drying chamber "with their own hands" so that the machine is more accepted by their society. - Provide examples of different dryer designs in Costa Rica and Burkina Faso for inspiration, and indicate the square footage necessary for the heat pump. - Provide a Frequently Asked Questions section in the user manual.
Closing	
1. Is there anyone else you think that would be beneficial to talk to further?	Akos did not have any further suggestions for people to talk to.

APPENDIX A.4: Interview Plan for Christoph Günner

Where, when, with whom, and how the interview will be conducted

- Where: Via Skype
- When: March 27th, 2015 at 4:00 pm (CET)
- Whom: Christoph Günner
- How: Introductions, inquiry, and closing all via conference

Which team members will be responsible for various tasks

- Note-taking: Mariana and Kathryn
- Introducing the team: Mariana
- Questioners:
  - Introductory questions: Mariana
  - Fruit dryer mechanics and operations: Kathryn
  - Market interest and availability of fruit: Kathryn
  - Social and cultural consideration: Kathryn
  - Labor requirements: Kathryn
  - Closing: Mariana
- Writing the summary: Mariana and Kathryn
- Reviewing the summary: All

Information Collected

Introductory questions, fruit dryer mechanics and operations, market interest, availability of fruits, social and cultural considerations, labor requirements, and scope of the project in Indonesia.

Interview Schedule (Questions order)

INTRODUCTIONS

- Introduce each group member
- Thank Mr. Günner for his time
- Explain our project
  - We are a group of students from Worcester Polytechnic Institute, working from now until May with NTB on the low cost heat pump fruit dryer. Our goal for our project is to broaden the impact of the fruit dryer by either improving the already existing fruit dryer and/or expanding it to new locations. We researched the background to better understand how the fruit dryer works and are now trying to understand completely the impact/effect it has had in order to further improve it.

Christoph Günner	
Question	Answer
Introductory Questions	
1. How did you get involved in business in Indonesia? How does this farmers cooperative work?	In Bali, Christoph is involved with a cooperative that works with small scale projects. About 800 farmers work with permaculture projects, producing cashews, cocoa beans, moringa powder, dried fruits (mangoes, pineapple, jack fruit, dragon fruit, papaya, etc.). Humidity is really high in Bali (cannot use solar dryers), so the cooperative traditionally uses oven dryers, which generates a lot of smoke. The cooperative needs to enhance the quality of the drying process, so Christoph is looking for alternative drying methods for Bali and other tropical countries with high temperature.
2. How did you find out about NTB's project? Why are you interested in the low cost heat pump fruit dryer?	Christoph started to google alternative dryers and found an article about the implementation of NTB's dryer in Burkina Faso. He read that fruits are dried at a lower temperature, and since the cooperative mostly deals with fresh fruits, he realized the low-cost heat pump fruit dryer would increase the quality of their dried fruits.
3. What are your plans for the implementation of the fruit dryer in Indonesia?	Christoph would like to implement one or more of the low-cost heat pump fruit dryer in the cooperative in Bali. The rainy season starts in November and he wants the first dryer to be installed by that time.
4. How will the fruit dryer be beneficial to this region? Who will it mainly benefit?	The fruit dryer will mainly benefit the farmers in the cooperative. Christoph is creating an NGO in Germany, which is investing its money to support small farmers and cooperatives in Bali. The NGO wants to help the products of the cooperative to reach external markets, since there is a production surplus. Cashew and cocoa beans are already sold to Germany.
5. Is there another fruit drying process already in place? If yes, how is it working and why are you now looking for a different dryer?	During the rainy season, oven dryers are mostly used. For the remaining months, solar dryers are used. However, the harvest season for most fruits coincide with the rainy season, so oven dryers are the main method used in Bali.

	For the oven dryers, fire is used to heat up the system, which creates a lot of smoke. Heat is transferred from the fire to the fruits through a piping system that does not allow for temperature regulation, causing many fruits to be burned. From Christoph's experience, the preferred temperature for drying fruits is 42 ºC because it allows for a uniform drying process (moisture is drawn out evenly throughout the fruit), enhancing the quality of the final product.
6. Who will be funding the implementation in Indonesia?	Currently, Christoph's NGO is funding the implementation from its sources, but the NGO is contacting the German embassy in Indonesia (the answer deadline is next week), the Indonesian embassy in Germany, and other private institutions. If it is not possible to obtain funding from these sources, the NGO has its own money to implement a smaller scale project (one dryer).
Fruit Dryer Mechanics and Operations	
7. Are air conditioners and materials (wood, metals) that could be used as spare parts readily available in Indonesia? Are there enough resources available to construct the fruit dryer itself?	The tourism industry in Bali is prominent, so air conditioners are frequently installed by local technicians. Therefore, it would not be hard to find the materials needed to install the heat pump fruit dryer.
Market Interest and Availability of Fruits	
8. Do you plan to sell the dried products to the local or external market?	The main goal is to sell the dried products to the external market (United States and mainly Europe). Christoph's NGO has its own brand, Organic Island, which currently distributes the products in Germany and is considering future trades with Czech Republic.
Social and Cultural Considerations	
9. Can you tell us about the culture in Indonesia? In the cooperative, how did people receive fruit drying technology?	Islam in the most commonly followed religion in Indonesia. In Bali, however, the majority of the population follows Hinduism. Hindu farmers generally work less hours than farmers from other parts of the countries because they participate in many religious ceremonies. Thus, they receive a smaller revenue at the end of month (some earn less than €1 per day). This is causing many farmers to sell their lands and move away from agriculture to work in tourism. Christoph's objective is to give extra revenue for farmers in Bali through the selling of premium dried fruits, so they can maintain

	their culture (Hinduism) and way of life (agriculture).
10. Do you foresee any possible problems that could occur during an implementation of the low-cost heat pump fruit dryer?	The leader of the cooperative is an engineer that studied in the UK, so Christoph's does not foresee any reluctance from the farmers during the implementation of the heat pump dryer. Problems with electricity can arise, but the cooperative has a diesel generator as backup. Also, there could be a financial problem, but Christoph's NGO is able to cover the costs of one implementation if necessary.
11. Are there any foreign policies in Indonesia regarding technology transfer?	A license is needed to import machinery from other countries into Indonesia. Also, technology importation taxes are very high. Christoph currently does not have data comparing the prices of importing the machinery or building it there. As soon as he knows exactly all materials needed, he can decide what is the best alternative.
12. Does the community have technological experience?	Many cooperatives have experiences with technology, but it is usually low tech. The oven dryer, for examples, consists only of a pipe system that uses an oven with fire, and air is smoked through these pipes. Besides the dryers, most people in the community have cell phones.
Labor Requirements	
13. Who would operate the dryer?	The dryer would be 100% operated by the workers in the cooperative.
14. Would the workers be paid? If so, by who?	Yes. The Indonesian NGO Tri Hita Karana is paying for the workers' salaries.
15. Do all the workers in the cooperative have all the necessary skills? If not, can they obtain training?	Christoph does not think all of them have the necessary skills, but the cooperative has the human resources to train them. The leader of the cooperative is an engineer and could provide the training.
Closing	
16. What can we do to help you in implementing the fruit dryer in Indonesia?	- The user manual would be very helpful for the implementation in Indonesia. Sending someone over from Switzerland costs €15,000, while the machine itself costs €3,000. Therefore, having a user manual would deduct the implementation costs. - It is important to include in the manual the exact list of all materials needed. The electrical part is the most

	important one, so it should not be excluded from the manual. - The construction plan would be very helpful, with illustrations of all steps involved in the assembly process. - Christoph is also interested in designing more advanced technologies for drying fruits and making powder out of it. He wants to develop innovative products.